Experiments in the Cultivation, Harvesting, and Retting of Jute in British Guiana

By M. D. ffrench-Mullen

I. Introduction

The production of jute fibre is almost entirely confined to the subcontinent of India, there being a relatively minor industry in Brazil. Jute is also grown in China but information on production is scanty. At the instigation of the Colonial Office, investigations were carried out in various Colonial territories to determine whether jute or other stem fibres could be grown with a view to producing spinnable fibre. It soon became apparent that economic production of stem fibres, where labour was scarce or expensive, would depend on the mechanization of production, particularly cultivation, harvesting and retting.

While small exploratory trials were being conducted in various territories to determine whether jute or other stem fibres, such as *Hibiscus* sps. and *Urena lobata* could be grown, investigations into possible ways and means of mechanizing stem fibre production began. A mission was despatched to the United States of America and Cuba from the United Kingdom, financed by an Economic Co-operation Administration (Technical Assistance) Scheme[1]. The Mission recommended that the problem of mechanization might best be solved by mechanizing the harvesting of the stems, separating the bark from the woody pith in the field and transporting the ribbon to the retting factory. Retting operations should also be mechanized as far as possible. They formulated a detailed scheme to implement their recommendations.

The report of the Mission and its proposals were considered by a 'Mechanized Production of Jute Committee' set up by the Colonial Office which agreed that experimental work should be carried out on the lines suggested by the Mission. With the co-operation of the Colonial Development Corporation, trials were carried out in 1950 and 1951 on crops of *Hibiscus cannabinus* at Mokwa in Northern Nigeria[1]. These trials proved that the downstriker ribboner machine that had been developed following the Mission's visit to the U.S.A. and Cuba could successfully strip the bark from stems of *Hibiscus cannabinus* and that the ribbon so produced could be handled, dried and retted, when bundled into stricks but not when handled as a continuous sliver of ribbon.

In 1951, following the success obtained in ribboning *Hibiscus cannabinus* in the Mokwa Trials in 1950 and the growth of jute varieties in preliminary trials in British Guiana over the period 1949-51, a Mission was appointed by the Colonial Office with the object of reporting on the suitability of British Guiana for the carrying out of large scale mechanized

jute growing and processing trials to start in 1952. The members of the Mission were:

H. H. Croucher, Director of Agriculture, British Guiana;
W. Mailer, Bookers Sugar Estates Ltd., British Guiana;
J. S. Oliver, British Jute Trade Research Association, Scotland.

The Mission reported favourably on the possibility of carrying out large scale trials in British Guiana and recommended the establishment of a pilot estate to grow and extract jute by the most economical means possible. The pilot estate was to aim at producing the best quality of jute suitable for hessian yarns spun on high speed modern machinery.

The British Guiana Fibre Research Co. Ltd., was formed in London in May 1952. A subsidiary company, the Berbice Fibre Research Co. Ltd., was registered in British Guiana in the same year with the object of carrying out the proposed trials in British Guiana. The immediate objectives of the company were to find the answers to the following questions:

(a) Could jute be grown satisfactorily in British Guiana and a high quality fibre produced?
(b) Could the cultivation, harvesting, retting, grading and baling of jute be satisfactorily mechanized or partially mechanized?
(c) Could the fibre be produced economically enough to enable it to compete on the United Kingdom Market with jute from Pakistan?

The scheme was financed for a period of three years, starting in 1952, by equal contributions from the Ministry of Materials and from the Jute Industry by means of a levy on each ton of raw jute sold by the Jute Controller. In 1956, it was decided to continue the scheme as part of the agricultural development programme of British Guiana financed by Colonial Development and Welfare funds.

In accordance with the recommendation of the Mission, Enterprise section of Rose Hall Estate in Berbice, belonging to and kindly made available by Bookers Sugar Estates Ltd., was developed and used by the Berbice Fibre Research Co. Ltd., for its work from 1952 to the end of 1956, and the majority of the work described subsequently in this paper was done in this area. To effect savings on capital expenditure, staff and research facilities, the field work was transferred from Enterprise, following the 1956 autumn jute crop, to the Central Agricultural Station at Mon Repos, East Coast Demerara. This move was to ensure that, in the event of closure of the Company, certain capital expenditure would not be lost by abandonment but would be available to the Station.

In October 1958 it was apparent that, although certain varieties of jute could be grown tall enough to give a satisfactory yield of fibre under suitable conditions and a practicable mechanized process had been developed covering all stages from land cultivation to harvesting, retting and baling, any commercial growing of jute would be hazardous. This was due to a number of factors including uncertainty of the weather, particularly dry weather essential for efficient seed bed preparation, soil toxicity problems in certain soil types, and cost of production. Consequently, it was decided that the research companies should be voluntarily liquidated forthwith, all fixed assets in British Guiana being handed

over to the British Guiana Government for the use of the Department of Agriculture on the understanding that experiments to solve the soil toxicity problems would continue on a small scale and that the existing cultivation, harvesting and processing techniques would be used for jute production if circumstances permitted. Active jute growing ceased with the harvest of the 1958 autumn crop and the retting of stocks of dry ribbon was completed in 1959 before the liquidation of the companies in that year.

Preliminary Trials (1949-51)

Preliminary trials with jute and possible jute substitutes were commenced in 1949 by the Department of Agriculture, British Guiana. The aim of these trials was to determine whether jute could be grown on the coastlands and give a reasonable fibre yield.

(a) The 1949 Trials

Two small plot trials were conducted on the Sophia Sugar Experiment Station, Demerara, one for fibre and the other for seed production. Six varieties of jute were planted on frontland clay soils with seed received from the Sudan for both trials. *Hibiscus sabdariffa* and *Urena lobata* were included in the fibre trial, yields of which were as follows:

TABLE I

Variety	Age at harvest	Calculated weight of green matter per acre in lb.	Calculated weight of dry fibre per acre in lb.
Corchorus olitorius (E.C.R.–586)	14 weeks	25,265	806
Corchorus olitorius (India)	,,	17,860	562
Corchorus olitorius (E.C.R.–585)	,,	15,246	479
Corchorus capsularis (E.C.R.–612)	,,	21,562	377
Corchorus capsularis (India)	,,	28,126	401
Hibiscus sabdariffa	,,	32,670	954
Hibiscus sabdariffa	24 weeks	47,045	1,892
Corchorus olitorius (E.C.R.–576)	,,	37,244	1,416
Urena lobata	,,	23,522	837

Plot size 1/435·6 of an acre.

The flowering of all jute varieties, save E.C.R.–576, started eight weeks after sowing on the 17th of May and became general two weeks later. The jute variety E.C.R.–576 together with *Hibiscus sabdariffa* and *Urena lobata* did not commence to flower until 19 weeks after planting.

The growth of *Hibiscus sabdariffa* and E.C.R.–576 was similar, both reaching a height of 9 to 10 feet at harvest, and was superior to *Urena lobata* and greatly superior to the other early flowering jute varieties. Although *Hibiscus sabdariffa* had not begun to flower at 14 weeks, one plot was harvested for comparison with the early flowering jute varieties.

The stems were retted in a navigation canal or middlewalk and the fibre was hand stripped, dried and despatched to the Tropical Products

Institute for testing. The results of this examination together with an examination of Table I showed that E.C.R.–576 was the most promising jute variety. It was decided that all efforts should be directed towards the development of jute rather than substitute fibres.

(b) The 1950 Trials

The decision to bulk up the seed supply of the jute varieties was not taken until May. Land to undertake this work was not available at the Sophia Sugar Experiment Station, and the trials had to be moved to block D of Reliance Estate, Anna Regina, on to heavy clay soils under rough pasture and poorly drained. Owing to the late decision to proceed with the trials, the spring dry season was over when cultivation started with the result that cultivation and drainage were inadequate and this had an adverse effect on germination and subsequent growth of all varieties.

Seven varieties of jute were planted between the 7th and 14th of July over 17 acres with local seeds of six varieties and seed from the Sudan which included one new *Corchorous capsularis* variety, E.C.R.–584.

The poor tilth and late planting resulted in unsatisfactory growth which, coupled with poor germination of some varieties, gave low yields of seed. All varieties, save E.C.R.–576, flowered within four to six weeks of sowing; E.C.R.–576 commenced to flower 16 weeks after planting. A total of 480 lb. of seed of all varieties was obtained of which 65 lb. was E.C.R.–576.

(c) The 1951 Trials

In February, authority was received to continue the bulking up of all jute varieties necessitated by the comparative failure of the 1950 plantings. The area of Reliance Estate planted in 1950 was again utilized, being expanded to 105 acres for this crop. The soil was a heavy clay, poorly drained under short grass pasture and light scrub. In spite of the fact that work started immediately on clearing, drainage, fencing, etc., and that ploughing began as soon as the land was dry enough to permit cultivation, bad weather, together with machinery breakdowns, adversely affected both the quality and speed of pre-sowing cultivation. Planting was planned to be completed by the middle of May but, instead, sowing commenced on the 30th of May and was completed by the 7th of June, save for 18 acres which were not sown until the 27th of June.

A total of 45·26 inches of rain fell in 21 weeks from the 4th of March to 28th of July. This adversely affected pre-sowing cultivation, germination and subsequent growth. The greater proportion of the planted area died back. However, *capsularis* varieties of jute appeared to withstand temporary water logging while the *olitorius* varieties did not. Five small plot trials on fibre production, seed rate, seed production and response to NPK fertilizers had to be abandoned because stands were uneven.

These preliminary trials indicated that:

(a) The variety E.C.R.–576 could be grown to a reasonable height for fibre production.

(b) All jute varieties, save E.C.R.–576, responded to the change in day length that takes place in British Guiana between July and August.

(c) The best planting time appeared to be about mid-April with the start of the rainy season.

(d) If new land were opened up for jute, then land preparation must commence at the beginning of the long dry season in August of the preceding year.

(e) The short dry season from February to April was unreliable.

II. Plant Production

Climate

British Guiana lies on the north east coast of South America between latitude 2 and 8 degrees north and longitude 57 and 61 degrees west. Jute trials conducted during 1949 to 1958 were confined to the coastal belt between latitude 6 and 7 degrees north.

On the coast the climate is marked by high rainfall and humidity with a relatively narrow diurnal temperature range. The mean annual rainfall varies from 80 in. in the east, where Enterprise Estate is situated, ascending to 110 in. in the west in which zone Reliance Estate occurs. The Central Agricultural Station and the Sophia Sugar Experiment Station are situated in the 90 in. rainfall zone. The mean monthly shade temperature varies from 79°F. to 82°F.; the daily range is generally 10°F. and rarely exceeds 14°F. Temperatures above 90°F. and below 70°F. are unusual. Humidity during the growing seasons is seldom below 85 per cent.

Comparing temperature and humidity with that of a typical jute area of India described by Finlow[2], it will be seen that although the mean monthly temperature is a few degrees lower in British Guiana, humidity is similar and there is no indication that either factor is unfavourable to jute.

The range of annual rainfall on the coast lands of British Guiana varies quite widely round the mean, there being a general indication of a 13-year weather cycle. The main wet season commences in late April and ceases in mid-August; the short wet season starts in December and ends in February. The long and most reliable dry season extends from September to late November while the short dry season of March to late April is much less reliable. The autumn jute crop should be planted in April while the spring crop should be sown in November, harvesting taking place in September to October and in March to April respectively. The

Table II

Pattern of Rainfall during Growing Periods.

Autumn crop Month	Spring crop Month	Rose Hall Estate Autumn Crop, Mean of 49 yrs. in.	Rose Hall Estate Spring crop, Mean of 49 yrs. in.	Calcutta Mean of 33 yrs. in.
May	December	10·75	8·94	5·74
June	January	10·93	8·69	11·43
July	February	9·93	5·32	12·89
August	March	6·19	5·29	12·16
Totals		37·80	28·24	42·22

total rainfall during the growing periods for both autumn and spring crops is similar to that of a typical jute area in India as illustrated in Table II, bearing in mind that any short fall in rainfall at the end of a growing period can be made up by irrigation in British Guiana.

As work proceeded, it became clear that the rainfall pattern was more variable than one would expect from an examination of annual rainfall figures particularly in connection with dry weather necessary for land preparation and the production of a fine seed-bed. Table III records the monthly rainfall at Enterprise for 1953 to 1956 together with the number of days in each month on which rain fell.

TABLE III

Month	1953		1954		1955		1956	
	Rain in.	No. wet days	Rain in.	No. wet days	Rain in.	No. wet days	Rain in.	No. wet days
January	10·88	24	11·78	27	5·89	21	14·79	17
February	17·15	28	4·92	11	3·41	12	5·05	13
March	8·79	19	6·68	17	7·96	21	3·41	14
April	7·80	18	23·33	25	6·88	11	2·53	9
May	10·51	26	8·34	24	9·86	18	11·17	22
June	9·62	18	11·92	22	11·55	16	11·56	22
July	9·98	18	7·53	22	10·38	16	5·96	17
August	2·65	5	11·75	21	2·91	8	17·53	18
September	6·19	10	2·52	13	4·54	8	9·08	15
October	0·93	5	5·89	13	4·12	7	3·51	12
November	0·69	8	9·94	20	8·72	14	7·41	8
December	6·07	19	9·09	19	21·74	26	16·88	23
Total	91·26	198	113·69	234	97·96	178	108·88	190

The mean annual rainfall at Rose Hall Estate for 48 years was 81·36 in.

During the period from 1953 to 1956 the rainfall was higher than normal and the number of days on which rain fell during the two cultivation periods was high, particularly in the main crop cultivation period of March to April. On clay soils, reasonably dry conditions are essential for efficient ploughing and subsequent drying out and working of the soil into a suitably fine tilth essential for jute. Furthermore, any delay in planting jute after April or November will result in a shorter growing period with reduced fibre yields. The abnormally wet weather adversely affected land preparation and time of planting and resulted in variable stands and growth and yield responses.

Table IV records the monthly rainfall totals for the two cultivation seasons. In March-April, high rainfall rendered adequate pre-sowing cultivation impossible for three years (1953-55) and low rainfall hindered the production of a fine tilth in the remaining three years. In the October-November period, 1954 was too wet while 1953 and 1957 were too dry. Conditions favoured cultivation in only two years out of five.

Adequate monthly rainfall data were available for Rose Hall Estate for

TABLE IV

Year	Monthly Rainfall in inches			
	March	April	October	November
1953	8·79	7·80	0·93	0·69
1954	6·68	23·33	5·89	9·94
1955	7·96	6·88	4·12	8·72
1956	3·41	2·53	3·51	7·41
1957	1·47	1·02	3·72	2·82
1958	3·25	14·87	—	—

the period 1907 to 1954. This was used to calculate the percentage probability of less than a certain amount of rain falling in any one of the cultivation months by the method developed by Glover and Robinson[3]. The percentages are shown in Table V for the months of March and October when dry conditions are necessary for ploughing.

TABLE V

Percentage probability of rain	Months	
	March	October
<5 in. . . .	47·8	81·0
<6 in. . . .	56·8	90·6
<7 in. . . .	65·2	96·0
Mean in. . .	5·24	2·97
Standard Deviation	4·44	2·28

Field experience indicates that less than 5 in. of rainfall are necessary, particularly in March, to permit effective ploughing and subsequent seed-bed preparation. On this basis reasonable conditions can be expected every second year in March and four out of every five years in October.

If planting is to take place in April and November on seed-beds possessing a fine tilth more than 5 in. of rain are required in April and November following less than 5 in. of rain in the months immediately preceding them. Table VI indicates that suitable conditions will occur every other year in March to April and every fourth year in October to November.

TABLE VI

Rainfall in March in.	Percentage probability of 5 in. of rain in April	Rainfall in October in.	Percentage probability of 5 in. of rain in November
<5	49·9	<5	26·6
<6	50·0	<6	28·0
<7	51·6	<7	30·2

Actual rainfall conditions experienced during pre-sowing cultivation and sowing of the autumn crop were in line with the calculated probability, namely that one out of every two years should be suitable. Considerable difficulty was occasioned by three consecutive wet years, as occurred in the period under review. Actual weather conditions experienced for the sowing of the spring crop were slightly better than calculated but this was offset by the lesser reliability of the December to February rains and the fact that varieties of jute suitable for spring crop planting were not found until 1955. Temperatures and humidity suited the crop. The unreliability of the rainfall distribution, particularly for pre-sowing cultivation, was found to be a major hazard to successful jute cultivation.

Soils

The main soil types of the coastlands of British Guiana are frontland clays, pegassy clay and pegasse, reef sand and riverside silt. The preliminary jute trials were conducted on frontland clay soils. The soils at Enterprise on which jute was grown from 1952 to 1956 were frontland clays with a slightly higher silt content than was found at the Central Agricultural Station where jute was grown on clay soils as well as on pegassy clay and deep sand soils. The last-mentioned is an intermediate soil type between frontland clay and reef sand.

Certain varieties of *olitorius* and *capsularis* jute have been grown to a satisfactory if variable height (7–14 ft.) on clay soils, fibre yields varying with height and uniformity of stand. On pegassy clay and deep sand soils these varieties have never reached a satisfactory height for fibre production although the *capsularis* grew better than *olitorius* varieties.

It is considered that the clay and sand soils of the coastlands are derived from clay silt and sand brought down from the interior by the main rivers and deposited on top of the then existing strata of the area. This material was deposited in the sea with the result that the base exchange capacity was initially dominated by sodium and magnesium ions with smaller amounts of calcium and potassium. The soil type bordering the coast is generally frontland clay followed by deep sand, reef sand, pegassy clay and pegasse as one proceeds inland. The whole of the cultivated coastlands are below sea level at high tide with the result that the cultivated coastlands have to be protected by a sea wall to prevent the entrance of sea water.

(a) Frontland Clays

Where undisturbed these soils are covered with natural swamp and marsh vegetation and contain appreciable amounts of salt. Following drainage and cultivation, the topsoil of up to 18 in. is a brown clay, the subsoil of 12 to 18 in. is a compact grey clay with red and yellow mottling resting on a grey-blue clay. The clay fraction is generally greater than 55 per cent. and often more than 60 per cent. Cultivated soils are acid, although acidity generally lessens with depth, with increasing salinity on typical frontland clay soils. Phosphorus is basically deficient while potassium is generally adequate on the soils of this type on which jute was grown. The organic matter status and total nitrogen are generally

low. High exchangeable sodium and magnesium and low calcium in the sub-soil are not uncommon. This soil type has an inherently poor structure and requires careful cultivation and good weather conditions to produce the tilth necessary for the successful growth of jute. The bulk of the major crops of the country, sugar-cane and rice, are grown on this soil type.

(b) Pegassy Clay and Pegasse

These soils are typically tropical peat soils which consist of anaerobically decomposed fresh water swamp vegetation overlying acidic leached white buttery clays. The friable black surface layer, varying from a few inches to several feet in depth, may contain 5 per cent. to 8 per cent. of organic matter but may be as great as 80 per cent. Phosphorus is deficient while potassium is generally adequate. The highly acid nature of these soils coupled with high aluminium iron and sulphides bring about toxic symptoms when the land is brought under cultivation, resulting in partial or complete growth failure. Jute was found to be intolerant of high aluminium and ferrous iron.

(c) Reef Sand

These soils are light sandy soils occurring as thin bands in the coastal clays, being generally medium to coarse in texture and of quartz type. They are unsuitable for jute.

(d) Riverside Silts

These silty clay soils comprise deposited alluvium on the banks of the rivers which are generally laid down in a narrow band a few hundred feet in width and lie parallel to the river. They are better drained as the land slopes back from the river bank and overlie a more clayey subsoil. Exchangeable bases are low, particularly potassium. The best of these soils could no doubt grow jute but, because of their narrow width, trials were not laid down on them.

(e) Deep Sands

These soils appear to be a transition soil between frontland clay and reef sand and are restricted in extent. As observed at the Central Agricultural Station, the surface soil is usually a silty clay with a subsoil of sand or sandy clay. The silty clay is similar to frontland clay while the subsoil may have appreciable amounts of aluminium and iron, both of which jute will not tolerate.

(f) Iron and Aluminium Toxicity

The preliminary trials indicated that the varieties of jute being grown would be adversely affected by poor drainage. Jute was therefore planted at Enterprise in 1952 on beds 27 ft. wide, beds being separated by interbed drains which were dug by machine. The spoil from the interbed drains was spread in a band, some 4 to 6 ft. wide, evenly over the bed. As the beds are cambered to their centres it often happens that subsoil is exposed on the edge of the bed for a distance of 1 to 2 ft. adjacent

to the interbed drain. It was found that jute adjacent to the interbed drain did not grow as well as or have as good a colour as that over the rest of the bed. This was due to the presence of less fertile subsoil either exposed by mechanical drain digging or brought to the surface and mixed with top soil by the drain digger. The effect was to reduce the height of the crop and the yield of fibre of jute grown alongside interbed drains compared with the rest of the bed.

This effect at Enterprise was partly corrected by heavier dressing of superphosphate and sulphate of ammonia along the edges of beds and by the addition of lime but was never entirely eliminated. This drain edge effect was repeated at the Central Agricultural Station on frontland clay soils but was found to be more severe on deep sands and pegassy clays. In some cases total failure of the crop on edges of beds occurred, and, often, the failure extended up to 6 ft. from the edge of the bed. It was found that *olitorius* varieties were more severely affected than *capsularis* varieties. The Chemistry Division of the Department of Agriculture was called in to study the problem in conjunction with the Company's agronomist.

Previous work by this division of the Department of Agriculture on the failure of cotton on pegassy clays had indicated that the cause was the presence of high concentrations of available aluminium affecting the root system and resulting in stunted corralloid roots. Similar roots symptoms were observed on stunted jute plants, aluminium causing necrosis at the root tip or immediately behind the meristematic region and leading to the destruction of the root system.

Work conducted in 1957 and 1958 has clearly shown that deep sands and pegassy clays contain levels of aluminium and ferrous iron toxic to jute and that there is a distinct difference in tolerance levels between the two species of jute, *C. capsularis* and *C. olitorius*, the former being more tolerant.

The mean of a set of typical analyses are recorded in Table VII.

TABLE VII

Soil Type	Site of Sample	Available			
		K_2O parts per million	Al_2O_3 parts per million	P_2O_5 parts per million	Fe parts per million
(*a*) deep sand	bed centre	129	1,880	31	107
" " "	bed edge	158	1,710	16	134
(*b*) deep sand	bed centre	—	200	—	66
" " "	bed edge	—	185	—	67
pegassy clay	bed centre	195	1,417	61	12
" "	bed edge	130	545	13	28

The failure of both species of jute on the above soils was attributed to one of three sets of conditions:

(1) The presence of high aluminium with high ferrous iron on deep sand (*a*) soil.

(2) The presence of low aluminium with high ferrous iron on deep sand (*b*) soil.

(3) The presence of high aluminium with or without high ferrous iron on pegassy clays.

The tolerance limits of aluminium for a fibre crop were provisionally set at 300 parts per million for *C. olitorius* and 500 parts per million for *C. capsularis*. The Al_2O_3 content of both pegassy clays and deep sand (*a*) soils was greatly in excess of these limits. Provided similar concentrations of this element are found in these soil types elsewhere in British Guiana they cannot be used to grow jute.

The role of ferrous iron in relation to aluminium was that neither species of jute could survive in a soil containing more than 15 parts per million of iron in the presence of high aluminium. The position is not so clear in the case of deep sand (*b*) when the aluminium content is comparatively low. In this case there is evidence that the physical structure of the solum plays a significant role. If a friable soil is available as compared with one with little or no crumb structure, *olitorius* jute will grow to a reasonable height in soil containing 83 parts per million Fe and 98 parts per million of Al_2O_3. Where the physical condition of the solum is bad this species has failed to establish on a soil containing 50 parts per million Fe and 98 parts per million Al_2O_3. The tolerance limits suggested for *olitorius* and *capsularis* jutes under poor physical condition of the solum are as follows:

(a) *olitorius* jute—15 parts per million Fe in the presence of up to 50 parts per million Al_2O_3.

(b) *capsularis* jute—20 parts per million Fe in the presence of up to 100 parts per million Al_2O_3.

Under good physical conditions of the solum the following tolerance limits have been suggested:

(a) *olitorius* jute—100 parts per million Fe in the presence of up to 100 parts per million Al_2O_3 or
15 parts per million Fe in the presence of up to 300 parts per million Al_2O_3.

(b) *capsularis* jute—100 parts per million Fe in the presence of up to 150 parts per million Al_2O_3 or
15 parts per million Fe in the presence of up to 400–500 parts per million Al_2O_3.

The toxic conditions described could possibly be corrected, if not too severe, by the liming of the soil, the oxidation of the ferrous iron being followed by fixation through the addition of phosphatic fertilizers. The lime would reduce acidity and lower the aluminium content as well as improve soil structure. Green manuring would also be advisable, supplemented by heavy applications of farmyard manure and/or compost. The above measures would require several years to produce their effect and would be very expensive both in materials and loss of productivity while correctives were being applied. Preliminary observations showed that the application of lime followed by frequent working of the soil on deep sand and pegassy clay soils had no effect on the growth of the jute crop but considerable and beneficial effect on the growth and yield of cowpeas.

to the interbed drain. It was found that jute adjacent to the interbed drain did not grow as well as or have as good a colour as that over the rest of the bed. This was due to the presence of less fertile subsoil either exposed by mechanical drain digging or brought to the surface and mixed with top soil by the drain digger. The effect was to reduce the height of the crop and the yield of fibre of jute grown alongside interbed drains compared with the rest of the bed.

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The tolerance limits of aluminium for a fibre crop were provisionally set at 300 parts per million for *C. olitorius* and 500 parts per million for *C. capsularis*. The Al_2O_3 content of both pegassy clays and deep sand (*a*) soils was greatly in excess of these limits. Provided similar concentrations of this element are found in these soil types elsewhere in British Guiana they cannot be used to grow jute.

The role of ferrous iron in relation to aluminium was that neither species of jute could survive in a soil containing more than 15 parts per million of iron in the presence of high aluminium. The position is not so clear in the case of deep sand (*b*) when the aluminium content is comparatively low. In this case there is evidence that the physical structure of the solum plays a significant role. If a friable soil is available as compared with one with little or no crumb structure, *olitorius* jute will grow to a reasonable height in soil containing 83 parts per million Fe and 98 parts per million of Al_2O_3. Where the physical condition of the solum is bad this species has failed to establish on a soil containing 50 parts per million Fe and 98 parts per million Al_2O_3. The tolerance limits suggested for *olitorius* and *capsularis* jutes under poor physical condition of the solum are as follows:

(a) *olitorius* jute—15 parts per million Fe in the presence of up to 50 parts per million Al_2O_3.

(b) *capsularis* jute—20 parts per million Fe in the presence of up to 100 parts per million Al_2O_3.

Under good physical conditions of the solum the following tolerance limits have been suggested:

(a) *olitorius* jute—100 parts per million Fe in the presence of up to 100 parts per million Al_2O_3 or
15 parts per million Fe in the presence of up to 300 parts per million Al_2O_3.

(b) *capsularis* jute—100 parts per million Fe in the presence of up to 150 parts per million Al_2O_3 or
15 parts per million Fe in the presence of up to 400–500 parts per million Al_2O_3.

The toxic conditions described could possibly be corrected, if not too severe, by the liming of the soil, the oxidation of the ferrous iron being followed by fixation through the addition of phosphatic fertilizers. The lime would reduce acidity and lower the aluminium content as well as improve soil structure. Green manuring would also be advisable, supplemented by heavy applications of farmyard manure and/or compost. The above measures would require several years to produce their effect and would be very expensive both in materials and loss of productivity while correctives were being applied. Preliminary observations showed that the application of lime followed by frequent working of the soil on deep sand and pegassy clay soils had no effect on the growth of the jute crop but considerable and beneficial effect on the growth and yield of cowpeas.

Varieties

The jute fibre of commerce is obtained from two species of the genus *Corchorus* namely *Corchorus olitorius* L. and *Corchorus capsularis* L. of the family Tiliaceae.

Both species have been known in India for several centuries. *C. olitorius* is a comparatively common wild plant in India while *C. capsularis* is rarely found out of cultivation. It appears that the former is indigenous to India while the latter was probably introduced into India.

The initial work during 1949 to 1951 was undertaken with seed introduced from the Sudan of both species. Subsequently importation of other varieties took place from India, Pakistan, Brazil, Australia, New Guinea and Suriname. In addition an *olitorius* variety, named Murray's jute, was found growing on a group of peasant farms near Enterprise. This variety was probably either brought in by immigrants from India early in the present century or escaped from a jute introduction made by the Department of Agriculture in the second decade of this century. Table VIII records the introductions.

TABLE VIII

Origin	Varieties of *C. olitorius*	Origin	Varieties of *C. capsularis*	Origin	Varieties of *C. capsularis*
Sudan	E.C.R.–576	Sudan	E.C.R.–584	New Guinea	1412
Sudan	E.C.R.–585	Sudan	E.C.R.–612	New Guinea	2111
Sudan	E.C.R.–586	India	*capsularis* India	New Guinea	2756
India	*olitorius* India	India	D. 154	?	New *capsularis*
India	040–753	Pakistan	D. 154	Suriname	104
India	'Chinsurrah Green'	,,	C. 41–13	Brazil	BZ–1
Pakistan	,,	,,	C. 39–212	,,	BZ–2
Brazil	BZ–5	,,	C. 42–NJ–412	,,	BZ–3
British Guiana	Murray's Jute	Australia	Queensland Jute	,,	BZ–4

All introductions save those from Brazil and Suriname were made with the help of the Tropical Products Institute and the Colonial Office. The Brazilian and Suriname introductions were made by the Company, the latter being obtained from the Dutch authorities in that country, having been introduced from Java. A few pounds of Brazilian seed in three separate lots were obtained from the Amazon basin. On arrival in 1953 all seed failed to germinate in laboratory tests. In spite of this, the seed was sown in the hope that a few plants would be obtained. A few plants grew and four distinct varieties were selected from them. The seed was carefully bulked and, on subsequent selection, one variety was found to contain two strains. In consequence five varieties from this introduction were recognized, one being an *olitorius* jute and the remainder *capsularis* varieties.

All introductions were field tested following bulking up of the seed over a number of years in both the autumn and spring crops before any

decision was taken to discard a variety. The potential of any variety as a fibre producer can generally be judged quite accurately during the bulking up process for seed, coupled with laboratory retting of a small sample of ribbon.

All the introductions from India, Pakistan, New Guinea and Australia, together with certain of the varieties from the Sudan, failed to grow to a satisfactory height for fibre production as all started to flower in four to six weeks from planting irrespective of whether they were sown for either the autumn or spring crops. All these varieties were prolific seed producers.

Of the remaining varieties the Sudan varieties E.C.R.–584 and E.C.R.–586, the Suriname variety 104 and Murray's jute showed some promise and were field tested for a number of years. They were eventually discarded because their flowering behaviour resulted in unsatisfactory fibre yields owing to shortness of stem.

The varieties that have proved suitable for fibre production due to their photoperiodic behaviour and satisfactory growth prior to flowering for the autumn and spring crops were as follows:

TABLE IX

The Autumn Crop (April-September)

Species	Variety	Time of Flowering
C. capsularis	BZ.–1	From the beginning of August
,,	BZ–2	,,
,,	BZ–3	,,
,,	BZ–4	,,
C. olitorius	BZ–5	,,
,,	E.C.R.–576	From the middle of August and normally 18-19 weeks following sowing

The Spring Crop (November-March)

C. capsularis	BZ–1	From the end of February
,,	BZ–2	,,
,,	BZ–3	,,

The two *C. olitorius* varieties suitable for fibre production will only grow properly during the autumn crop. If planted for a spring crop in November, they commence to flower in December when 2 to 3 ft. high. The *C. capsularis* variety BZ–4 behaves similarly. When these varieties are planted in mid-April, the Brazilian strains will reach a height of 9 to 11 ft. under good field conditions by the beginning of the harvest in the second half of August. E.C.R.–576 which flowers about two weeks later than these varieties will attain heights of 10-12 ft. under good field conditions and a crop a little over 13 ft. in height has been obtained.

The autumn crop varieties of jute react to the change in day length that occurs between July and August. Records show that day length is at a maximum in June with 12½ hours. This reduces gradually in July into August to about 12 hours, at which point all varieties that have not

flowered four to six weeks after planting begin to flower except for E.C.R.–576. There has been one major exception to the photoperiodic behaviour described. This was in 1957, an exceptionally dry year, when flowering of the Brazilian varieties was delayed until September.

Of the six varieties of jute found suitable for fibre production, only E.C.R.–576 is heterogeneous. Field observations indicated that selection would probably yield early and late flowering strains. Efforts were made to establish these two strains by mass selection in 1954-56 but ended in failure because it was impossible for senior staff to devote the necessary time to this work. A further attempt was made in 1957 but this work was interrupted by the closure of the scheme. The Brazilian strains are generally homogeneous because they were selected from a small number of parent plants.

Finlow[2] and others have described the botanical characteristics of both species of jute. As in India the *C. olitorius* varieties grow taller than the *C. capsularis* strains and other general characteristics are similar save that all strains will not tolerate water-logging when young, particularly in the seedling stage, *C. capsularis* being more tolerant to such conditions than *C. olitorius*. Neither species will continue to grow following flooding, *C. olitorius* dying back while *C. capsularis* puts forth a mass of adventitious roots and the resulting fibre is very rooty. The major characteristics of the six proven fibre varieties under suitable field spacing for fibre production are briefly described. If the spacing in the field is too wide all varieties will branch profusely, the only exceptions found being BZ–1 and 104.

(a) *C. olitorius*, Variety E.C.R.–576

This is characterized by straight unbranched stems with branching at the crown just before the start of flowering. It is a good ribboner when harvested at flowering or shortly afterwards at optimum maturity for fibre. Satisfactory ribboning can be extended beyond this point always provided conditions are not too dry. If overmature for ribboning, the pith or wood of the stem becomes supple and will not snap during ribboning. This results in ribbon containing an excessive amount of pith, known as shive, which interferes with subsequent operations. Its removal adds appreciably to processing costs. Fibre quality is good, being in the high quality fibre bracket, and the variety shows some resistance to mite attack (Plate I).

(b) *C. olitorius*, Variety BZ–5

This is characterized by straight unbranched stems in good fibre stands with tendency to branch if the spacing is at all wide. It is a good ribboner with fibre about equal in quality to E.C.R.–576 and resistant to mite attack.

(c) *C. capsularis*, Variety BZ–1

This variety is characterized by possessing an unbranched stem of larger diameter than the other varieties and a distinct yellowish green stem, grey at the butt end and with growth habit and leaf colour which

permits of easy field identification. It differs from BZ–2, BZ–3 and BZ–4 by having a foliaceous stipule. This variety offers no difficulties when harvested very overmature for fibre. The pith snaps cleanly at all stages of maturity. The variety is very susceptible to mite attack as well as cercopids and the fibre is coarse tending to be very rooty, although dry ribbon of this variety rets easily. The coarseness of the fibre results in its realizing a price, grade for grade, equivalent to that of good *Hibiscus cannabinus* or *Urena lobata*.

(d) *C. capsularis*, Variety BZ–2

This variety is virtually identical to BZ–4 vegetatively, differing mainly in flowering behaviour and seed pod characters. It ribbons satisfactorily but has a strong tendency to branch throughout its length and, if the spacing is at all wide, develops very strong branches, particularly in the first 2 ft. from ground level. These branches will grow to lengths of 6 ft. or more parallel to the stem. Plants with well-developed branches seriously interfere with ribboning. The fibre is much finer than that obtained from BZ–1 but is slightly coarser than that produced from BZ–3. It is susceptible to attack by mites.

(e) *C. capsularis*, Variety BZ–3

This variety (Plate II) is a satisfactory ribboner having a tendency to branch if spacing is unsatisfactory. The branching habit is similar to BZ–2 but not as marked. The fibre produced is the finest of the *capsularis* varieties grown on a field scale. Natural crossing has taken place in the field with BZ–1 and certain of these hybrids have been selected. A cross combining the easy ribboning character and unbranched habit of BZ–1 with the fibre quality of BZ–3 would undoubtedly provide a most useful variety. This ease of crossing provides a most promising line of breeding work coupled with field selection of natural crosses. It is also more resistant to mite attack than BZ–2 being similar to BZ–4 in this characteristic.

(f) *C. Capsularis*, Variety BZ–4

This variety did not do at all well at first and was nearly discarded. It is a satisfactory ribboner, being similar to BZ–3 in its branching habit rather than BZ–2. As already noted it is practically identical in vegetative character to BZ–2. It also differs from BZ–2 in being suitable for autumn crop planting only and in being more resistant to mite and other pest attacks.

(g) Varieties Discarded

The basic reason for discarding varieties was that, due to early flowering, they failed to reach a height of 6 to 8 ft. in field trials. All the Indian and Pakistan varieties with the exception of 'Chinsurrah Green' seldom grew 3 ft. high before flowering commenced. Some plants of 'Chinsurrah Green' did reach 8 ft. on one occasion but repeated trials failed to yield a uniform stand of reasonable height.

The Sudan varieties E.C.R.–585 and E.C.R.–586, particularly the

latter, did grow to 6 ft. on occasions, but, by the time this height was reached, the plants were overmature for fibre and very branched.

Murray's jute was grown in small patches to over 6 ft. but, owing to its early flowering, it was impossible to achieve greater height. The variety was not a good ribboner because the pith would not snap cleanly. The seed of this variety under field conditions was found to germinate over four weeks. Treatment of the seed in commercial sulphuric acid for two minutes followed by thorough washing and drying resulted in 80 per cent. germination in three to five days.

The variety 104 was very similar to BZ–1 in growth habit, ease of ribboning, coarseness of fibre and susceptibility to mites, but differed from it by flowering about 20 days earlier and therefore failed to grow tall enough for fibre production.

The Australian and New Guiana varieties all flowered out before attaining a height of 3 ft.

The flowering of all early varieties in an autumn crop was delayed until the end of July by extending the day length for several hours, using ordinary electric light on a laboratory scale.

(h) Selection and Breeding

The necessity for selection work on the variety E.C.R.–576 became apparent after the 1953 Autumn Crop because the variety appeared to contain early and late flowering strains as well as a small number of plants with red pigmented bark in any one crop.

It also became clear that any improvement in the number of varieties that would grow to a satisfactory height under British Guiana conditions would only be achieved by selection within the six proven varieties and by a breeding programme using the proven varieties and some of the discarded varieties from India and Pakistan which were potential yielders of high quality fibre.

Preliminary mass selection of early and late flowering strains of E.C.R.–576 failed because of the inability of trained staff to devote time to this project. With the appointment of an agronomist in 1956, this work was put in hand although it was somewhat handicapped in the early stages due to the movement of the field work from Enterprise to the Central Agricultural Station.

The desirable commercial characters of the six varieties have been described. In the breeding programme comprising pure line and mass selection and hybridization, the following characters were laid down as desirable for varieties suitable for mechanized production.

(a) A pith that snaps cleanly even when the crop is slightly overmature for fibre production.
(b) An unbranched stem for the greater length of the plant.
(c) A non-coarse fibre of high quality.
(d) A high fibre content in the bark.
(e) Non-susceptibility to mite and flea beetle attacks.
(f) Early and late maturing varieties to enable the harvesting period to be spread.

In addition to the six proven varieties, the following Indian, Pakistan and Sudan varieties were used: *capsularis* India, 'Chinsurrah Green', E.C.R.–585 and E.C.R.–586.

The results of this work after 18 months active field operations were as follows:

(a) *capsularis* varieties may be crossed with some difficulty, with the exception of BZ–2 which it has been found impossible to use as the female parent.

(b) *olitorius* varieties may be crossed, with the exception of 'Chinsurrah Green' when it is used as the female parent.

(c) Attacks by mites hinder hybridization and, if severe, may make such work impossible.

(d) Seeds obtained from *capsularis* crosses proved viable, while that from *olitorius* crosses proved non-viable in all save one cross.

(e) The varieties BZ–1, BZ–2, BZ–4, BZ–5 were found to be homogeneous while BZ–3 was found to be contaminated with natural field crosses of BZ–1 × BZ–3.

(f) Selection of non-branching strains is a most promising line of work.

(g) Pure-line and selection for early maturity proved to be impossible at the Central Agricultural Station because of soil toxicity problems.

Rotations

It was originally thought that, if jute could be grown in British Guiana, it would be confined to the autumn crop, being sown in April and harvested in August to October. Consideration was therefore given to the possibility of developing a rotation which would enable the land to be fully cropped throughout the year. The need to develop a rotation became less demanding once three of the BZ jute selections were found in 1955 to be suitable for cultivation as a spring crop.

Sugar-cane and rice are the two major crops on the coastlands of British Guiana. The jute varieties available will not tolerate poor drainage conditions and have to be grown on land with drainage at least as good as that required for sugar-cane. No difficulties were foreseen in taking a crop of jute off land between two sugar-cane cropping cycles. With the co-operation of Rose Hall Estate, some 20 acres of land on which the final ratoon sugar-cane crop had just been harvested were planted in jute for the autumn crop in 1953 without disturbing the internal field drains. The area was re-planted with sugar-cane immediately after the jute harvest. There was no doubt that jute could be included without detriment in a rotation with sugar-cane, and probably with advantage to the subsequent sugar-cane cycle, because of the additional cultivation to which the land was subjected and to fertilizer and organic matter residues.

Land under sugar-cane only becomes available for jute once every four or five years, depending on the number of ratoon crops taken. In consequence a sugar-cane cum jute rotation did not overcome the problem of fully utilizing the land primarily intended to grow jute. Consideration was therefore given to growing a spring crop of rice between each autumn crop of jute. The main rice crop in British Guiana is grown as an autumn crop, only a very small proportion of the annual acreage under rice being

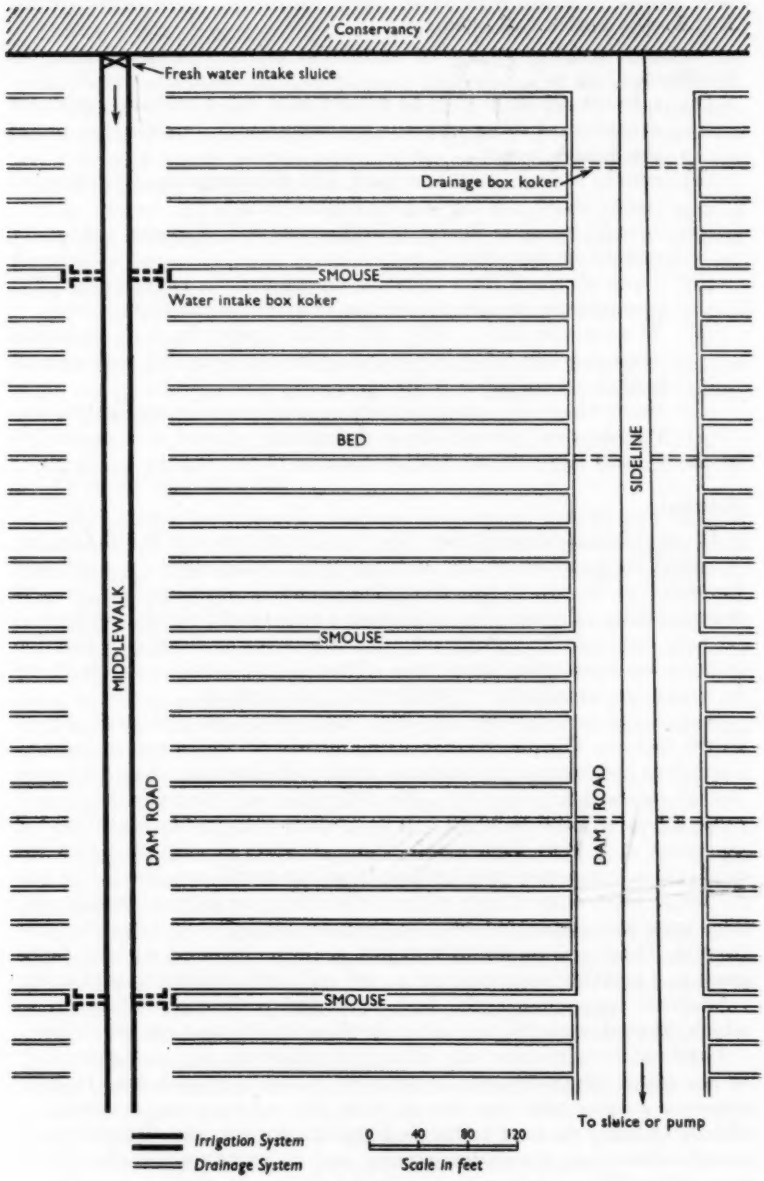

FIG. 1. Jute field layout

grown as a spring crop. This is because yields per acre are often less than in the autumn and a late spring harvest might adversely effect the following autumn crop yields.

Jute would not grow on the usual British Guiana field lay-out of land used for rice owing to the lack of internal field drainage. The supply and field control of irrigation water and drainage, where such is available in rice areas, is of a deplorably low standard while, by comparison, these operations on sugar estates are of a relatively high standard. In 1951, field observations indicated that a substantial improvement of irrigation and drainage control in rice gave increased yields. It was therefore decided to determine whether rice could be grown on a normal field lay-out for jute which comprised an empoldered area of 10 to 15 acres, internally subdivided into cambered beds two rods wide, adjacent beds being separated by interbed drains of 2½-3 ft. top width (Fig. 1).

The first trials of growing rice on a bed lay-out were laid down in December 1953. Rice was sown broadcast on the beds and irrigation water was let into the field drains following germination, the level of water being raised in the field as the rice grew until the whole rice crop was growing normally under flooded conditions. In spite of severe paddy bug attacks and a delayed harvest due to rain a most satisfactory yield of 20·6 bags (each of 140 lb. net) of paddy per acre was recovered. Field losses from shattering as a result of the delay in harvesting and depredations by birds were severe.

Subsequent spring crop trials confirmed the results obtained, namely that a satisfactory spring crop of rice could be taken on land the field lay-out of which was suitable for growing jute and sugar-cane. Equally good yields were obtained by growing rice on a bed lay-out for the autumn crop. The yields obtained were above average for rice grown in the area under customary cultivation conditions. As a result, a certain alternative crop to jute was obtained for both the spring and autumn crops. If unfavourable weather conditions were experienced before the start of the autumn and spring crops, preventing the preparation of seed-beds with the necessary fineness of tilth for jute rice could be sown and a crop was assured.

When using this technique of growing rice certain factors have to be borne in mind. Beds should not be too cambered; the flatter they are the better. If the camber is too severe, this can be reduced by harrowing down the centre of the bed. After sowing, the seed should be lightly disced under or put under with a zig-zag harrow. If weather permits, the crop will benefit by a light rolling following harrowing: alternatively, if soil conditions are favourable, the harrowing may be dispensed with, provided that the beds are rolled. Irrigation water can be let into the interbed drains and raised to the lip of the drain immediately after post harvest cultivation, the beds being wetted from underneath, so hastening germination if dry weather is experienced. The water level is raised as the crop grows until the top of the bed is covered by 2 to 4 inches of water; the control factor being the rate of growth of the rice growing alongside the interbed drain. A slow movement of water is permitted through the field provided that the height of water in the irrigation canal

makes this possible; if not, the field must be topped up by pumps as required. A certain amount of differential ripening takes place on the bed between the centre and both edges; the greater the bed camber the greater this differential. This differential does not seriously interfere with harvesting. It is generally considered that rice grown on a cambered bed lay-out would offer no difficulty in being harvested by self-propelled combines although no actual field trials were made.

The growing of a spring crop of rice followed by an autumn crop of jute had one major disadvantage in that it was possible that wet weather would occur in March delaying the harvest. This, in turn, would delay preparatory cultivation for the following autumn crop of jute with the result that the latter crop would be planted late or on soil lacking the necessary fineness of tilth. An autumn crop of rice followed by a spring crop of jute did not have this disadvantage because of the greater reliability of the September to October dry season for cultivation. The rice crop acted as a good cleaning crop for weeds and had a beneficial effect on the structure of the heavy clay soils.

The possibility of utilizing a shorter term crop than rice as a rotation crop was investigated. A cowpea variety, 'Mottled Brown', was grown as a spring crop with success on cambered beds at Enterprise. The crop is very susceptible to temporary water-logging. Yields tended to be variable depending on weed competition, planting time, method of sowing and seed rate. Yields on the clay soils of Enterprise varied from 336 lb. to 692 lb. per acre including plant losses occurring alongside interbed drains due to flooding. When the effective area of the beds lost by flooding was discounted, a broadcast crop covering several acres yielded 1,039 lb. per acre. On deep sand and pegassy clay soils at the Central Agricultural Station, a broadcast cowpea crop planted as a cover crop following a jute crop failure, yielded at the rate of 310 lb. per acre over 55 acres. In this area beds that had received agricultural lime at the rate of one ton per acre gave yields varying from 775 to 1,550 lb. per acre.

The possibility of growing maize as a spring crop on a field lay-out suitable for jute was also investigated. The crop was drilled with a Ferguson Universal seed-drill. At Enterprise, the rows adjacent to the interbed drains were adversely affected by water in rainy weather but, in general, a good even crop of maize was grown. Leaf-eating caterpillars and the sugar-cane stem borer (*Diatraea saccharalis*) attacked the crop, the latter causing considerable loss. Heavy rain occurred during the last half of the pollination period and resulted in many light cobs at harvest. In spite of these adverse factors yields varied from 1,471 lb. of dry cobs per acre on beds receiving no manure to 2,879 lb. on beds that received a complete fertilizer. It was concluded from this trial that maize showed some value as a rotational crop, with jute for the spring crop season, but returns would depend on the vagaries of the weather and the pest complex. Maize was subsequently planted at the Central Agricultural Station on deep sand soils and the above conclusion was confirmed.

Black-eye peas and soya beans were tried out at Enterprise but the varieties tested failed to make reasonable growth.

The Company undertook to conduct trials with cotton on behalf of

PLATE I. A good crop of E.C.R.-576

PLATE II. A good crop of BZ-3

PLATE III. Digging out drain-heads with the Din-kum Digger

PLATE IV. Severe mite damage to apex of BZ-1 plant

PLATE V. Cutting jute with a Ferguson mid-mounted mower

PLATE VI. Cutting jute with a Cutrake

PLATE VII. Removing jute from Cutrake

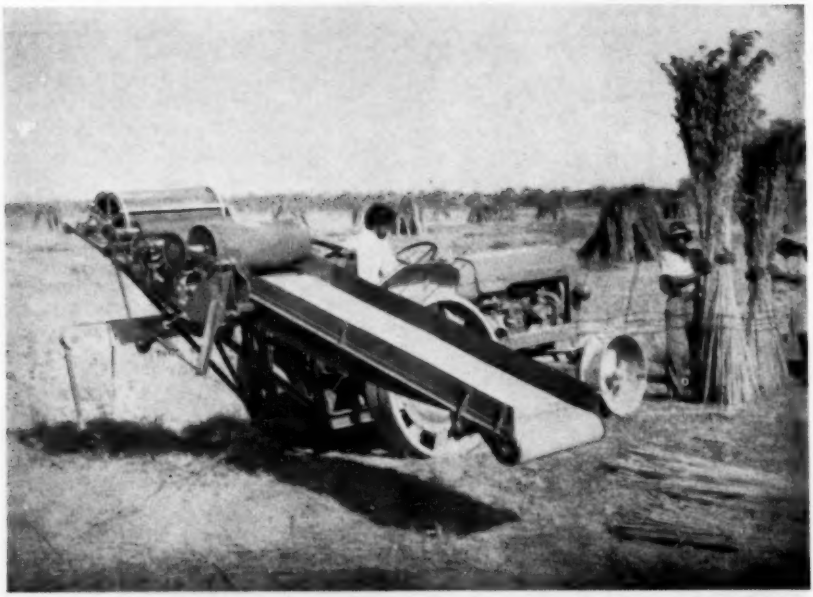

PLATE VIII. The original Elcom ribboner

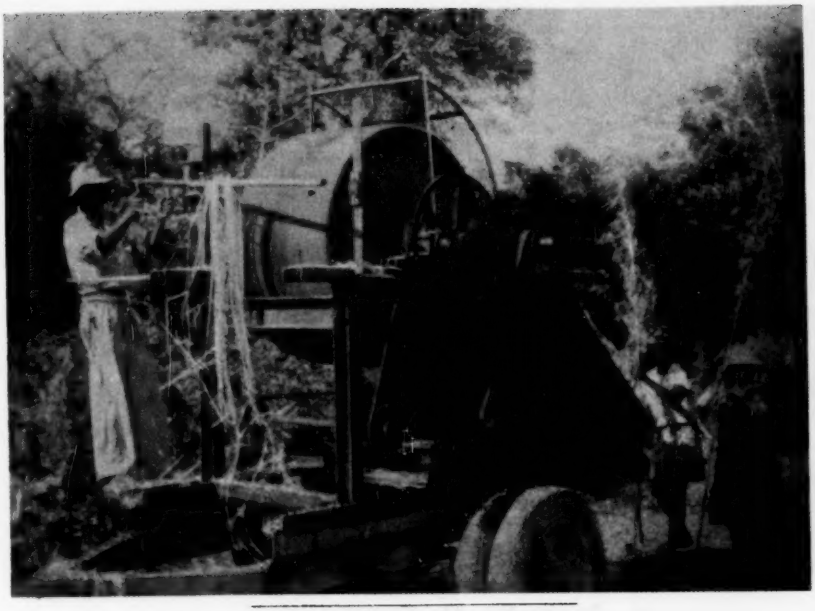

PLATE IX. The Hay ribboner

PLATE X. The Elcom ribboner converted to a trailed downstriker ribboner

PLATE XI. The Enterprise ribboner

PLATE XII. Ribboners at work

facing page 251]

the Department of Agriculture during the period 1952 to 1955, with a view to determining whether cotton could be grown as a spring or autumn crop and whether it could be used in rotation with jute. By 1955, it was clear that the only varieties showing any promise on Enterprise soils were the black-arm resistant Sakel cottons from the Sudan. The crop was too risky to be considered suitable for a jute rotation although the field lay-out was suitable if the crop was planted on ridges. Major considerations against the establishment of cotton as a crop were: (a) the high incidence of cotton stainers together with the presence of numerous wild hosts of these insects; (b) the unreliability of dry sunny weather for harvest and (c) the large labour force required for picking at a time when both sugar-cane and rice also require labour.

The Company discontinued work on cotton in 1955 and expressed the view that there were so many other areas in the world suitable for growing cotton that to continue to try and re-establish this crop on the coastal clays of British Guiana under unfavourable weather conditions was unnecessary and would probably result in failure. In the event, this occurred in 1957 when the cotton experiments that had been carried on from 1955 by the Department of Agriculture were closed down.

It was found possible to grow jute in rotation with sugar-cane, rice, cowpea and possibly with maize. The need for rotation crops remained even after the discovery of jute varieties that could produce a fibre when grown as a spring crop.

Drainage and Irrigation

The cultivation of jute requires an elaborate canal system for drainage and irrigation which determines the field lay-out (Fig. 1). As has been recorded jute can be grown successfully on sugar-cane fields (Fig. 2), the lay-out of which is similar to that for fields primarily designed for jute. The effective surface area under crop in a jute field is about 88 per cent. of the total field acreage. The surface area lost for cropping purposes comprises the area occupied by interbed drains, the four-foot drain, the middlewalk and sideline dams which also act as roads, and the smouses or large bunds on the other two sides of the field. In sugar-cane fields, the area contributing to this loss comprises the internal field drains as described, with the addition of the cross canals. The middlewalk and sideline dams may or may not be cultivated.

The estates or sections of an estate comprise long, rather narrow, strips of land running at right angles to the coast or river. These sections are empoldered by dams to permit drainage and irrigation. There are two distinct canal systems serving each strip, a low level drainage canal running along one side and known as the sideline, and a high level irrigation and navigation canal on the opposite side and known as the middlewalk. The distance between the middlewalk and sideline may vary between 1,000 and 2,000 ft. Individual fields vary in size but are generally of 10 to 12 acres, each being bounded on two opposite sides by a middlewalk and a sideline. In a sugar-cane lay-out the remaining two sides of each field are defined by branch irrigation and navigation canals, known as cross canals, to facilitate the loading and transport of the crop to the

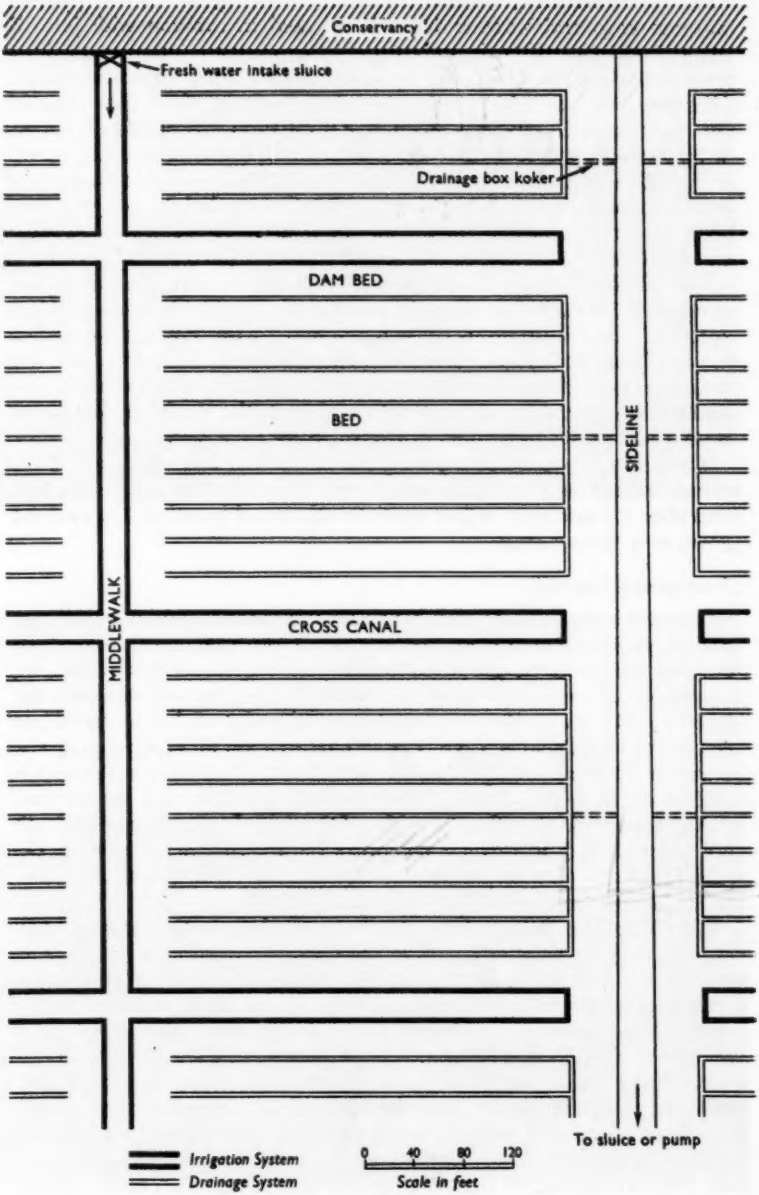

FIG. 2. Sugar-cane field layout

factory. In jute these cross canals are not necessary and are replaced by smouses large enough to prevent the movement of flood irrigation water from one field to an adjacent one. The base of the smouses needs to be about 10 ft. wide.

The sidelines discharge into the sea or river by gravity drainage at low tide through sluice gates or kokers or through pumps with capacities ranging from 400 to 600 tons per minute, or by means of both systems combined. The drainage system for sugar-cane and jute is such as to enable the equivalent of at least 1½ in. of rain over the whole empoldered area to be removed within 24 hours.

Irrigation water is obtained, either from the conservancies lying at the back of estates, or from fresh water creeks by pumping or gravity. The conservancies are simply fresh water swamps contained within the boundaries of the main river systems in which rainfall is conserved. They may be 200 to 300 square miles or more in area.

Each field for jute is divided up into beds 25 ft. wide, separated by interbed drains of about 2½ ft. top width, the beds and interbed drains being generally at right angles to the middlewalk and sideline. Bed widths of 31 ft. and 37 ft. (2½ and 3 rod beds) proved satisfactory for jute cultivation but a 25 ft. width was found most suitable because the bed tended to dry out quicker, enabling implements to be put to work earlier. The interbed drains discharge into a larger drain, known as the four-foot, situated at the sideline end of the field and running parallel with the sideline. The four-foot discharges into the sideline by a sluice box or box koker which passes through the sideline dam. Each field is protected by dam beds at the sideline and middlewalk sides of the fields and by smouses on the remaining two sides. Irrigation is effected by making a cut in the middlewalk dam bed after closing the box koker leading into the sideline and raising water in the field drains. If the field is to be flood irrigated it may have to topped up by pumps should the level of the water in the middlewalk be insufficient to complete the irrigation by gravity. The cost of gravity irrigation inclusive of closing the box koker is 66 cents per acre and requires 1·85 man hours per acre. Equipment available for topping up comprises 6 in. Sigmund pumps delivering 1,200 gal. per minute driven byFordson Major petrol tractors. Cost of irrigation by small pumps of this size is $4.31 per acre with a man hour per acre requirement of 0·13 (W.I. Dollar = 4*s.* 2*d.* Stg.).

It was found that a growing jute crop could generally be irrigated adequately by seepage of water through the bed, provided that the water was raised up to the lip of the interbed drains and held there for three to four days. This method was not altogether satisfactory for germinating a crop unless the beds possessed little or no camber. Quick flooding before sowing, or sowing followed by rolling and then flooding, was found to be more satisfactory to force germination. Considerable care was necessary when flooding, not only to allow the water to rise smoothly and without fuss but to discharge it in a similar manner to avoid grave silting up of the field drains. This method of irrigation by seepage across beds was found to be practicable for all crops grown by the Company on clays, sands and pegassy soils.

The construction and maintenance of sidelines and middlewalks was carried out by draglines and the dam beds were formed by bulldozers assisted by graders. The sidelines and middlewalks vary in width, the former vary from 20 to 40 ft. top width with side slopes of 1 : 2 to 1 : 3 and depths of around 10 ft. while the latter vary around 20 ft. in top width with depths of 4 to 5 ft.

When the scheme started the internal field drains were dug by a combination of a Cuthbertson double mouldboard type drain digger pulled by heavy crawler tractors, and by hand labour. The cost of hand digging was high and labour was often scarce. Ways and means were therefore sought to reduce drainage costs and dependence on labour by the introduction of other mechanical aids. The performance of the Cuthbertson machine was improved by slight modifications to the wings, coulters and body of the machine for operating in clay soils. In the hands of a well-trained operator on task work this machine was found to dig adequate interbed drains at a cost, excluding depreciation of the drain digger and tractor, of 91 cents per acre and at a rate of five acres per hour. The ends of interbed drains that discharge into the four-foot cannot be finished by the Cuthbertson machine and have to be hand finished. This adds considerably to drainage costs.

Various types of drain cleaning and digging machines were imported and tested. The Dinkum Digger was the only machine to prove satisfactory once the bucket was re-designed. The machine as received was fitted with straight-sided buckets and there was no means of ejecting a sticky clay. Preliminary trials on digging out the heads of interbed drains and digging four-foots indicated that the machine would do the job more quickly than by hand with a saving in cost and man hours, provided that the spoil could be discharged automatically from the bucket and a bucket could be designed to give a finished drain with a side of reasonable slope. The problem was put to the manufacturers and the suggestion made that a bucket with a 30-in. top width and 10-in. bottom width without a back might solve the problem. Such a bucket was made and an ejection device was added to assist the emptying of spoil. The new bucket solved the twin problem of ejection of sticky clay spoil and the tapering of the side of the drain. The cost, excluding depreciation of the Dinkum Digger and Fordson Major tractor when digging out the heads of the interbed drains left by the Cuthbertson machine, was $1.24 per acre at a rate of $\frac{3}{4}$ an acre per man hour. When digging four-foot drains the cost was $1.02 per acre at a rate of 0·94 of an acre per man hour. The higher cost when digging out drain heads is accounted for by the additional time spent in moving the machine from drain head to drain head (Plate III).

Pre-Sowing Cultivation

The preparatory tillage required for both species of jute is similar. Finlow[2], Sanyal [4] and others have stressed the need to provide a clean seed-bed with a fine tilth to obtain satisfactory crops. It has been stated by Sanyal[4] that any amount of labour expended on preparing a first-class seed-bed, free from weeds, is justifiable for jute.

Under Indian conditions every effort is made to produce what would be described in the western hemisphere as an unusually fine, clean seed-bed prior to sowing. This is achieved by five or six ploughings and ladderings with probably one or two rakings before the final laddering[4]. This results in a level fine seed-bed, with the soil well pulverized and no surface lumps. The ploughing and laddering is done with animal draft.

The only record of seed-bed preparation by mechanical means comes from Brazil[5], where it is recorded that jute was planted with a seed drill similar to that used for drilling alfalfa following ploughing and disc harrowing. A similar technique was in use in Cuba for *Hibiscus cannabinus*.

The Commission envisaged that cultural techniques that had been found suitable for sugar-cane in British Guiana would be required for jute and, on this assumption, heavy crawler tractors with bulldozer equipment, together with a 'Shugadisc' and mouldboard ploughs, Rome harrow and Cuthbertson drain digger were ordered. The technique of sugar-cane cultivation at this time was that, at the end of the harvest, if the field was not flood fallowed, a bulldozer roughly filled in the four-foot and any other field drains that might interfere with ploughing. The field was then deep ploughed to a depth of 12 to 15 in., and allowed to weather if time permitted. The interbed drains were dug by the Cuthbertson machine, the beds formed by a grader and harrowed with Rome discs, the four-foot dug and the interbed drains completed by hand. The field could then be planted or put under a flood fallow.

During these investigations, the following tractors and implements were used at one time or another in an effort to devise suitable preparatory tillage techniques for the production of as fine a tilth on seed-beds as possible under prevailing soil and weather conditions. Heavy crawler tractors with bulldozer attachments of the International Harvester 'TD 18' and Fowler 'Challenger 3' types were employed, as well as medium crawler tractors of the Fowler 'VFA' type and light wheeled tractors of the Fordson Major and Ferguson types. Implements used comprised heavy and medium weight trailed three and four-furrow disc and mouldboard ploughs such as the 'Shugadisc', and 'Dragoon'; disc and mouldboard Ferguson and Fordson mounted ploughs; trailed disc harrows of the Rome and 'Baron' type; Ransomes 'HR 20' and Ferguson offset mounted disc harrows; toolbars fitted with various types of tynes; ploughing discs and ridger attachments and rotary hoes.

The land available to the Company at Enterprise in 1952 had been under rough pasture for years and sections of it had been used in World War II for the production of swamp rice. The first 157 acres of the 260 acres finally cultivated were prepared for sowing in the usual way for sugar-cane save that, after harrowing with Rome discs, all beds were rotovated in order to obtain as fine a seed-bed as possible. The work was carried out by Rose Hall Estate in accordance with the cultivation programme devised by a future officer of the Company, work being undertaken by the estate in anticipation of the formation of the Company. Cultivation began in November 1951, and the success achieved in obtaining a fine, deep cultivated seed-bed was greatly assisted by the partial failure of the 1951-52 spring crop rains. The failure of the spring crop rains was

perhaps unfortunate because of the misleading impression gained that weather conditions in February to mid-April would favour production of a fine tilth so necessary for jute. In the event, weather conditions were never as favourable again at Enterprise for preparatory tillage operations.

From a study of the cultivation technique described above and such other factors as the composition of the top and subsoils, capital cost of equipment, and tilth required for jute, it was decided to concentrate on two lines of investigation over the next few years; namely improvement of the existing cultivation technique, and the possibility of using less expensive wheeled tractors and implements.

It was clear that on clay soils land under jute would have to be ploughed out following each crop and the cultivation technique described would be wasteful as well as undesirable, due to the constant admixture of less fertile subsoil with top soil. The complete re-making of the field drainage system also seemed unnecessary. Trials were conducted into the possibility of gathering the beds to their centres when ploughing. This had the advantages of producing a cambered bed, less admixture of sub and top soil and avoided the total destruction of the interbed drains.

A suitable technique for gathering beds was worked out, the final drain edge cut being achieved by the land side plough wheel straddling the interbed drain. This technique precluded the use of the trailed mouldboard plough, as the drain edge cut can only be done with a disc plough. The drain edge cut puts a considerable strain on the plough. The 'Shuga-disc' is a valuable heavy plough for bringing in new land, or under very dry conditions when weight is required to assist penetration. Its very asset under dry conditions is a disadvantage under wet conditions as the plough tends to bog down. The lighter 'Dragoon' four-furrow disc plough proved suitable for forming beds as did the Case 3/4 furrow disc plough, the latter providing the best inversion of the furrow slice when properly adjusted. Under good conditions or for a second ploughing, the 'Dragoon' and Case ploughs could be pulled by a Fowler 'VFA' tractor at a ploughing depth of 10 to 12 in. Under wet or very dry conditions, these ploughs had to be handled by heavy crawler tractors care being taken not to pull the plough apart. This technique of gathering to the centre of the beds has become standard practice.

The Rome harrow is of considerable value when bringing in new land, for harrowing down deep-ploughed land and for harrowing out jute stubble before rotovation or ploughing by light wheeled tractors. It cannot prepare a fine tilth and, when used on cambered beds, tends to leave a depression half-way between the edge and the centre of the bed which is undesirable on clay soils due to the sensitivity of jute to water-logging.

The possibility of ploughing with wheeled tractors and mounted ploughs was investigated. Beds could be ploughed to their centres at Enterprise under good weather conditions to a depth of 10 in. quite satisfactorily using disc ploughs, except that a strip, 1 to 2 ft. in width on either edge of the bed could not be touched. A single furrow offset mouldboard plough was tried out but the implement was too light and could not be sufficiently offset. It was thought that a toolbar fitted with plough

discs set to throw outwards might solve the problem. With the assistance of Ransomes, Sims & Jefferies Ltd. of Ipswich, this Company's 'C 68' toolbar was suitably equipped with dropper arms and two pairs of ploughing discs, each pair mounted to throw outwards. In this way the problem was solved. Given suitable weather conditions, wheeled tractors of the Fordson Major and Ferguson type fitted with mounted ploughs and with a suitably-equipped Ransomes 'C 68' toolbar were capable of ploughing land which had been brought into cultivation for jute or similar crops by heavy crawler tractors and matched equipment. Moreover, less damage was done to the interbed drains using this equipment than was done by crawler tractors using trailed ploughs. This involved a considerable reduction in capital expenditure or, alternatively, an increased acreage ploughed in any given period for the same capital outlay. Advantage could not be taken of this finding, however, because of the uncertainty of having weather suited to the use of wheeled machines in any year.

A rotovator fitted to a Fordson Major tractor following the discing out of jute stubble, produced at Enterprise an excellent but shallow tilth in suitable weather conditions which, however, occurred infrequently. On clay soils the tilth produced tended to be too shallow for jute and there was a tendency for a consolidated layer or pan to form immediately below the tilled layer. On the other hand, a rotovator produced a most satisfactory deep fine tilth when used to produce a seed-bed after deep ploughing and harrowing, as was demonstrated in 1952. The operation was considered to be too slow when account was taken of the restricted time available for cultivation, and the cost of rotovation was high.

In addition to the Rome harrow, the lighter and less expensive four-gang trailed 'Baron' harrow fitted with cutaway discs was found suitable for heavy harrowing when penetration was assisted by weights. It was used for primary as well as secondary harrowing and to put the land in a sufficiently fine state to permit the light mounted disc harrows to work satisfactorily. These were used to prepare the final seed-bed and were always used in pairs, one being permanently offset to deal with the harrowing of the edges of the beds. They were also fitted with cutaway discs after it was found that plain discs were of little use. The cutaway disc was found to be essential on all types of disc harrow working on clay soils if efficient work was to be performed under varying weather conditions. The prejudice against disc harrows in British Guiana was probably due to the fact that they were put to work fitted with plain discs.

Mounted toolbars fitted with rigid or spring loaded-tynes with various types of points were found useful for cleaning out patches of weed on beds left by other implements.

Various types of wheel attachments were tested to improve the traction and flotation of rubber-tyred wheeled tractors under wet soil conditions. The cage wheel attachment was found to be the best of these devices and was essential for transportation and cultivation during rainy periods.

As a result of these investigations, an improved system of cultivation was devised using crawler tractors. The method involved less soil disturbance and admixture when ploughing was undertaken; a reduction

both in the cost of implements and in the cost of heavy tractors because the use of lighter implements meant a corresponding reduction in the size of crawler tractor required; and a general reduction in the overall cost. A technique was devised for land cultivation when weather conditions were favourable, using light wheeled tractors and associated equipment with considerable savings in capital. The employment of the heaviest and more costly agricultural equipment was shown to be unnecessary once the land had been cleared and brought into cultivation.

The complicating factor in land cultivation in British Guiana is the unreliable nature of the dry seasons which makes it unrealistic for anyone to rely on cultivating land for jute or similar crops with light wheeled tractors because they will only do efficient work within a fairly narrow range of soil moisture conditions on clay soils. On the other hand, if cultivation equipment is restricted to heavy crawler tractors and ancillary implements, there is the real danger that cultivation will be undertaken under wet conditions when the land should never be worked. Experience dictates that if land is to be farmed in jute in British Guiana it would be necessary to employ a balanced fleet of agricultural tractors with associated implements for cultural operations. Such a fleet might consist of equal numbers of heavy and medium crawler tractors and twice as many wheeled tractors as for any one group of crawlers. In addition, any organization would require to invest more capital in cultivation machinery than would normally be necessary because of the need to take advantage of every spell of dry weather by putting as many machines into the field as possible.

The following are certain representative costs of various pre-sowing operations excluding depreciation on the tractor and implements. In all operations labour was paid on a task basis. Ploughing with a four-furrow Case disc plough and heavy crawler tractor, such as the Fowler 'Challenger 3' or International Harvester 'TD 18', cost $2.47 per care at a rate of 1·31 acres per engine hour. A second ploughing using the Case plough with a Fowler 'VFA' Crawler tractor cost $2.22 per acre at a rate of 0·83 acres per engine hour. Filling in drain heads before ploughing, using a heavy crawler tractor with bulldozer equipment, cost 33 cents per acre at a rate of 6·44 acres per engine hour. Harrowing with Rome discs with a heavy crawler cost $1.26 per acre at a rate of 2·30 acres per engine hour while the Fowler 'VFA' with the 'Baron' harrow covered 3·05 acres per engine hour at a cost of 58 cents per acre. Mounted harrowing with the Fordson Major tractor cost 38 cents per acre at a rate of 3·84 acres per engine hour while the Ferguson tractor, doing only the edges of the beds with an offset mounted harrow, did 3·97 acres per engine hour at a cost of 23 cents per acre.

Using a combination of mechanical tillage techniques suited to weather conditions at any one time, there is no doubt that a seed-bed comparable with that used by the Indian farmer can be produced on the light sand reef and pegasse soils of British Guiana. On clay soils the quality of the final seed-bed depends on weather conditions; in particular, periods of dry sunny weather with occasional heavy showers are necessary to facilitate breakdown of the clay. Given good weather conditions, a com-

parable seed-bed to that used in India can be obtained on clay soils by the use of mounted harrows or a rotovator assisted, under certain conditions, by mounted rollers.

Sowing

Finlow[2] stated that both species of jute in India were sown broadcast at a rate of 10 lb. per acre, the land then being lightly ploughed and laddered. Ghose and Patel[6] in 1945 and Sanyal[4] in 1953 stated that broadcast seed rates for *C. capsularis* were 8 to 10 lb. per acre and, for *C. olitorius*, 5 to 6 lb. per acre. When a hand-pushed jute seed drill, developed under the auspices of the Indian Central Jute Committee, was used for row crop sowing the seed rates recommended by Sanyal[4] were 5 to 6 lb. per acre and 3 to 4 lb. per acre respectively for *C. capsularis* and *C. olitorius*. In a review of jute cultivation practices in 1951, the United States Department of Agriculture[7] recorded that the Indian Government recommended a seed rate of 8 lb. per acre for *C. capsularis* and 5 lb. per acre for *C. olitorius*, provided that the germination percentage of the seed was high.

In the preliminary trials at Anna Regina, a broadcast seed-rate of 8 lb. per acre was used. The resulting stands were very dense and it was felt that the seed-rate could be reduced giving a saving in seed which was in short supply.

Both species of jute were sown at the rate of $4\frac{1}{2}$ lb. per acre in 1952 for the autumn crop at Enterprise. The seed was sown either by a hand-operated fiddle sower or hand broadcasted by women, the seed being bulked with a sand filler in proportions varying from 1 lb. of seed to 4 to 8 lb. of sand. Even broadcasting was obtained with either method, the speed of work being 5 to 6 acres per man day when fiddles were used and $1\frac{1}{2}$ to 2 acres per woman day when seed was sown by hand.

Following further investigations, fiddle broadcasting was adopted as the standard method of sowing both species of jute. Even broadcasting over the bed was obtained without using a filler by arranging for the operator to walk up the centre of the bed when there was no wind. Under cross wind conditions, with wind speeds of from five to eight miles per hour, even coverage was obtained by the operator walking along the bed in such a manner as to leave about the two-thirds of the bed surface to leeward. The fiddles sowed a two-rod bed with a single run down the bed and three-rod beds with two runs. The completeness of coverage was easily checked by the supervisor who had only to observe whether seed was reaching the interbed drain. Such observations were facilitated if there was a little water in the bottom of the drain. The cost of fiddle sowing was 29 cents per acre including transportation but excluding the value of the seed. The basic seed-rate for both species was 2 lb. per acre with seed possessing a germination percentage greater than 90. The seed-rate was adjusted upwards as the percentage germination fell below 90. Seed counts and weights of both species were found to be similar to those recorded in India [4, 8]. Varieties of *olitorius* were found to average 18,000 seeds per ounce and *capsularis* varieties 8,500 seeds per ounce.

In spite of lower numbers of *capsularis* seed per lb. compared with *olitorius*, it was found necessary to sow at identical seed-rates to achieve an even stand in the field. Being smaller, the *olitorius* seed has a smaller seed reserve which affects establishment under unfavourable weather conditions. It also germinates more slowly than *capsularis*, possessing a harder seed-coat, which also affects the establishment of an even stand.

Contrary to the opinion expressed by Ghose and Patel[6], it was found desirable to supply any gaps in a sown field by hand broadcasting, using sand as a filler, provided that re-sowing was done within 10 days of the original sowing. If carried out later, the supplies never attained the same height as the surrounding crop. The cost of supplying amounted to 14 cents per acre.

Observations made during the preliminary trials and with *Urena lobata* in Fiji some years previously indicated that, if jute could be grown as a rowcrop, a more uniform fibre crop both as to stem diameter, unbranched stems and height would result. Moreover, seed production might be increased if the crop were sown as a row crop at much wider spacings than would be permissible for fibre production.

A Ferguson 'Universal' seed drill fitted with disc coulters was tested in 1952. A seed-rate of 2 lb. per acre was obtained but the drill deposited the seed at depths of 1½ to 2 in. below the surface. This proved much too deep, with the result that germination was negligible. Difficulty was also experienced with the camber of the bed, the seed tending to be sown deeper towards the centre of the bed.

This seed drill was subsequently modified by replacing the disc coulters with Suffolk coulters in an effort to reduce the depth of sowing. This would probably have been successful if the effect of the camber of the bed could have been overcome. It is considered that this drill fitted with Suffolk coulters would plant jute satisfactorily in continuous rows at any inter-row spacing from 6 in. upwards, provided that the land being sown was comparatively flat. The successful use of this drill would mean that the rows would have to be thinned following germination.

Check row planting was considered preferable to continuous planting in the row and Stanhay and Catchpole drills were imported for trial. Suitable field conditions for trials never occurred but, in barn tests, the Catchpole was found unsuitable as it deposited clusters of about 27 seeds. On the other hand, the Stanhay, using belts designed for each variety, deposited from two to five seeds in clusters along the row. This would be very satisfactory in the field. The improved models of the Stanhay should be tested by anyone attempting to sow jute or jute substitute fibres for fibre production, where soil and weather conditions permit these drills to operate.

Under Indian conditions, *C. capsularis* may be sown before and during April while *C. olitorius* is usually sown at the end of April or in May. Time of sowing trials indicated that the most suitable time for sowing E.C.R.–576 was during the first half of April if suitable weather occurred. The sowing of this variety in May resulted in a reduction in crop height. All the BZ varieties should be sown in the last half of April, later sowings adversely affecting crop height. The varieties BZ–1, BZ–2 and BZ–3

should be sown in the last half of November if a spring crop is to be grown.

Investigations were carried out into the possibility of increasing the yield of seed of both species by check row planting with wide spacings of up to 4 × 4ft. for comparison with seed production from a normally broadcast crop. With wide spacings, greater than 1 × 1 ft., profuse branching occurred, the profusion increasing as the spacing became wider except in the case of the varieties 104 and BZ–1 where the stems remained unbranched for two-thirds of the height of the plant, branching only taking place near the top of the plant. As the number of branches per plant increased so did the seed yield. It is necessary to hand-pick seed from widely spaced seed bearers which is costly. This cost is not outweighed by the increased yield. It was decided that in view of seed yields from broadcasted crops and the mechanization of threshing, wider spacing for seed production was only justified when it was desired to bulk up a small quantity of seed as rapidly as possible.

Post Sowing Cultivation

Various authorities [2, 4, 5] stress the need for thorough preparatory tillage and the fact that no amount of post sowing cultivation can make up for any shortcomings in the tilth on which the crop is sown. This is also true in British Guiana and is what one would expect from experience with crops of similar seed reserves in temperate climates.

Areas sown by hand require a light zig-zag harrowing following sowing and, weather conditions permitting, benefit from a light rolling, using locally-designed smooth surface mounted rollers with Ferguson or Fordson Major tractors. With crops sown with fiddles, rolling was the only operation carried out immediately after sowing if weather conditions permitted. These rollers were sometimes used to break and smooth down a rough tilth immediately before sowing if lack of dry weather prevented the mounted harrows from doing so.

The rollers were simply welded cylinders of $\frac{1}{8}$th in. steel plate fitted with stub axles running in wooden bearings and mounted in hangers which were bolted on to the standard Ferguson and Fordson Major toolbar frames. Rollers of 12 in. and 18 in. diameters were made in 6 and 8 ft. lengths. The 12 in. diameter roller, 6 ft. long, was found to be most suitable for cambered beds while the 18 in. diameter roller, 8 ft. long, was useful for farm road maintenance when water ballasted. All rollers were capable of being filled with water. This type of roller was found to be effective and cheap to construct. The cost of operation exclusive of depreciation was 24 cents per acre at a rate of 4·73 acres per engine hour.

(a) Thinning

At high seed-rates of eight lb. to the acre, two to three thinnings are required and the cost is prohibitive under British Guiana conditions of high wage rates compared with India. Moreover, there is insufficient labour available to undertake this work at the optimum time.

At the standard seed-rate for fiddle sowing, thinning is necessary but is much reduced. Thinning may be carried out in conjunction with

weeding or as a separate operation, depending on circumstances. As a separate operation, thinning an average crop by hand to a spacing of 6 in. costs 89 cents per acre and requires four man-hours per acre. This operation, as well as weeding, is normally carried out by women.

(b) Weeding

The amount of weeding required during any crop varies considerably and primarily depends on the efficiency of seed bed preparation which, in turn, is controlled by weather conditions affecting pre-sowing cultivation. At Enterprise the weed position was made worse by the appearance of the grass *Echinochloa colonum* which spread rapidly both by vegetative means and by seed. Where good preparatory cultivation could not be given and where this grass had become established and had seeded in the previous crop, jute sown on what appeared to be a clean seed-bed would be choked out by the grass, which germinates more rapidly than jute.

Ample evidence was obtained that, as weed incidence increased in a crop, so was the growth of the crop reduced; a high incidence would result in total failure of the crop for fibre production. Under normal conditions the cost of hand weeding would be $4.60 per acre, requiring about 20 man-hours. The main weeds were various sedges and grasses.

No satisfactory method of weed control was found at Enterprise other than hand weeding. The amount of weeding that was required depended directly on the thoroughness of the pre-sowing cultivation and on the crop history of the particular field. When cultivation was poor, the cost of weeding became prohibitive and often weeding was not worth carrying out even if it could be done at the optimum time. Time did not permit trials to be carried out on such methods of weed control as extended flood fallows, two of three successive swamp rice crops, or green manure cum cover crops, which would probably have brought the weed complex under better control.

Jute is sown at the start of the wet seasons. As the soils suited to this crop in British Guiana are heavy clays the use of mechanical tools for weeding is out of the question. Even if a light tractor with a toolbar could travel over the beds in work the resulting puddled soil and general mess would prevent such an operation.

The problem of sedge control could have been easily dealt with by the application of the herbicide 2, 4-D. In trials, both species of jute proved to be more susceptible to this weedicide than the sedges, and rates below one pound per acre of acid equivalent destroyed the crop. PCP and TCA at economic doses proved useless against *Echinochloa colonum* and other grasses.

At the Central Agricultural Station 'Dowpon' was tried with a view to controlling grass growth in field drains as well as the crop. The results of these trials are being published by Mr. G. D. Baxter elsewhere but, for completeness, it can be said that 'Dowpon' controlled the following grasses in field drains when applied in two low volume applications, each at the rate of 2 lb. per acre with a 7 to 10 day interval between applications: *Digitaria chinensis*, *Eriochloa punctata*, *Hymenachne amplexicaulis*, *Leersia*

hexandra, *Panicum laxum*, *Paspalum conjugatum* and *Paspalidium geminatum*. 'Dowpon' was found to control *Echinochloa colonum* growing in association with young jute at a rate of $\frac{3}{4}$ lb. per acre applied in three applications at a rate of $\frac{1}{4}$ lb. per application. The *olitorius* jute is more susceptible to 'Dowpon' phytotoxicity than is *capsularis*, being prone to leaf malformation, leaf scorching and severe chlorosis of the leaf margin. The control of *Echinochloa colonum* can be achieved in a *capsularis* crop with the first spray application taking place 14 days after sowing, the remaining two following at seven-day intervals. With an *olitorius* crop, the first application occurs 21 days after sowing, subsequent applications at seven-day intervals.

The cost of grass control in field drains by 'Dowpon' is slightly higher than hand weeding but is more lasting in effect. The cost of grass control in a jute crop by 'Dowpon' is less than by hand labour where infestation is severe. It is clear that the most critical period in a jute crop is the first four weeks following sowing and, although chemical grass control has resulted in a much more even stand, there is no evidence yet that it has had any major effect on the subsequent height of the crop. It is possible that the effect on crop height was masked at the Central Agricultural Station by soil toxicity.

The elimination of water hyacinth in a middlewalk in 1953 was achieved by spraying all infested sections of the canal with 2, 4–D amine at a rate of $2\frac{1}{2}$ lb. acid equivalent per acre in high volume. The susceptibility of jute to this herbicide can be judged by the fact that severe damage occurred from drift in light wind 100 yards to leeward of the canal. All subsequent reinfestation of the canal by water hyacinth brought in by the irrigation water was dealt with by spot spraying.

Manuring

No source of organic manures being available at Enterprise, investigations were confined to the effect of inorganic fertilizers and agricultural lime. Observation trials in 1952 were based on a NPK mixture in which N was applied in the form of sulphate of ammonia at 40 lb. of N per acre, P in the form of superphosphate or basic slag at a rate of 40 lb. per acre of P_2O_5 and K in the form of muriate or sulphate of potash at the rate of 40 lb. per acre of K_2O. The basic slag was applied prior to sowing and lightly disced under. The remaining fertilizers were applied either singly or as various mixtures immediately before or after sowing or about four to five weeks after germination as a top dressing.

The most important result of this work was the finding that a reasonable crop height could not be obtained without the application of fertilizers. The effect of nitrogen on growth was apparent for eight weeks following application. Nitrogen plus phosphate applied as superphosphate gave a greater growth response compared with nitrogen alone. Superphosphate appeared superior to basic slag and agricultural lime appeared to benefit the crop.

As a result of these trials the basic fertilizer dressing for jute was provisionally fixed at 30 lb. of N and P_2O_5 per acre applied in the form of sulphate of ammonia and superphosphate. A $3 \times 3 \times 3$ factorial testing of levels of nitrogen, phosphate and limestone gave a significant response

to nitrogen at 1 per cent. point and a second 2 × 2 × 2 × 2 factorial testing of levels of nitrogen, phosphate, potash and limestone gave a similar result for nitrogen with the addition of significant responses at the 1 per cent. level for phosphate and limestone and at the 5 per cent. level for the interactions PL, NPL and NKL. These trials confirmed that the basic fertilizer dressings for jute at Enterprise should be 30 lb. each of N and P_2O_5, the latter being required in a quickly available form such as superphosphate.

In 1954, both statistical and observation trials confirmed that phosphate and nitrogen were essential for adequate crop growth, there being no change in levels of application. Split applications of nitrogen were found to be advantageous and the discing under of superphosphate with one-third of the total nitrogen application (10 lb. of N) immediately before sowing was superior to phosphate alone, followed by top dressings of nitrogen after germination. Subsequently, difficulties were experienced in applying phosphate and part of the nitrogen dressing immediately prior to sowing because, in the presence of seed of a grass such as *Echinochloa colonum*, the nitrogen had the effect of stimulating the growth of the quicker germinating grass to the detriment of the jute crop. Consequently, the technique could only be used in conditions where this weed problem did not arise.

The most successful technique evolved for clay soils with a grass problem was that of discing under granular superphosphate at the standard rate of 30 lb. of P_2O_5 per acre immediately before sowing, followed by the split application of nitrogen in the form of sulphate of ammonia at the rate of 15 lb. per acre of nitrogen applied three or four weeks after sowing and at the same rate about six weeks later. If it were possible to apply one-third of the total nitrogen application immediately prior to sowing, then the remaining two-thirds of the application would be broadcast as a top dressing six weeks after sowing, on completion of thinning and weeding.

Response to small dressings of agricultural lime were variable. The effects of heavy dressings were not studied because the cost of the lime, which had to be imported, would preclude its use at rates of several tons per acre.

One would expect that the incorporation of organic matter into the heavy clay soils at Enterprise as well as the clay and sandy soils at the Central Agricultural Station would benefit the crop. This was confirmed by field observations in 1953 and in subsequent years. Wherever leaf and shive left on a bed by the ribboner were incorporated into the soil, the subsequent crop stood out from the rest of the bed by being taller and better grown. Undoubtedly, the incorporation of organic matter into the clay soils would benefit crop growth. The harvesting technique of ribboning the crop in the field, thereby leaving about seven-eights of the green weight of a fibre crop as crop residues on the field, would benefit the clay soils over a period of years. The use of a green manure cum cover crops would be of v alue and might be essential in heavy soils low in organic matter and with a tendency to build up a severe weed problem, in spite of crop residues left in the field after ribboning.

Fertilizers and agricultural lime were broadcast by hand mainly by women. Spinner-type broadcasters operated from the power-take-off shaft of a wheel tractor were tested. They worked satisfactorily but there was some loss of fertilizers in the interbed drains. In unfavourable, wet conditions they could not be used without damaging the tilth of the bed. The Ferguson 'Universal' seed-drill was fitted with a fertilizer attachment which worked efficiently. Unfortunately, this drill is unsuitable for sowing jute on cambered beds.

Costs of hand broadcasting fertilizers per application, including transportation and wages but excluding the cost of the fertilizer, were as follows:

TABLE X

Type of Fertilizer	Cost per acre	Man-hours per acre
	$ c.	
Sulphate of Ammonia . .	0 58	2·31
Granular triple Superphosphate	0 60	2·36
Muriate of Potash . . .	0 54	2·13
Limestone at 1 ton per acre .	9 03	36·95
Limestone at 2 tons per acre .	10 34	40·78

Pests of Jute

During the preliminary trials, no pest of major importance was recorded but minor infestations of flea beetles and chrysomelids occurred. With the commencement of comparatively large scale plantings in 1952 the problem of pests arose.

In 1952, flea beetles and, to a lesser extent, chrysomelids attacked the crop with some severity. Damage comprised the eating of the leaves giving a shot hole effect, as well as damage to the outer tissues of the bark which would callous over leaving greyish brown oval spots. This bark damage was superficial in that it did not damage the fibre contained in the bark but affected subsequently the production of clean fibre. The production of callous spots on the bark depended on the degree of infestation of flea beetles; in a severe attack many spots would be produced on the bark of a single stem. It was found that these spots would not ret easily and that, often, when retting was completed and the fibre washed, many of these spots would remain adhering to the fibre, producing a specky fibre which commands a lower price. The *olitorius* jutes appeared to be more susceptible to flea beetle attack than *capsularis* jutes. Minor damage was also caused by cercopids (*Clastoptema sp.*) and a semi-looper caterpillar.

In 1953, the pest incidence was similar to 1952 save that mites were noted on *capsularis* jute. In 1954, flea beetles with chrysomelids were again prevalent but cercopid attack became serious, particularly on seed crops. Spittle masses of cercopids usually occur in the leaf axils and around the growing points of the plants and effectively destroy the flowers and flower buds, causing serious loss of seed in an uncontrolled attack. In addition, mites severely attacked the variety 104 when the crop was half-grown,

effectively retarding growth. This variety appeared to be much more susceptible than other *capsularis* varieties grown, including the varieties BZ–1, BZ–2, BZ–3 and BZ–4. This apparent major difference in susceptibility was disproved in 1955 and was probably occasioned, in 1954, by the fact that the BZ strains were grown in an isolated field well away from the bulk of the crop. The *olitorius* varieties growing nearby were not attacked by mites and were resistant, this resistance having been confirmed in subsequent crops.

In subsequent years, the major pests attacking jute in each crop were mites, flea beetles, chrysomelids and cercopids, whether at Enterprise or the Central Agricultural Station. The semi-looper caterpillar was a minor pest in each year.

Mites have become the main pest of *capsularis* jute and the major pest problem in jute in British Guiana, the more so as, of the six varieties of jute proved suitable to the country, four are *capsularis* varieties, three of them being grown both in the autumn and spring crops. When the problem first arose in 1954, it was thought that there were several species of mites involved and the Entomologist of the Department of Agriculture considered that the major species was a mite belonging to the genus *Tetranychus*. In 1957, it was determined at the Central Agricultural Station that the mite attacking jute on the station was the yellow mite, *Hemitarsonemus latus*, Banks.

The first obvious field symptom of a mite attack is that the young developing leaves near the apex of the plant curl under, the whole leaf being crinkled and often developing a bronzed sheen. If the attack is prolonged these deformed leaves never recover and drop prematurely. However, if weather conditions become unfavourable to the mite, the young leaves that are attacked late may partially recover and subsequent leaves will develop normally as the attack subsides, the plant growing away from the site of attack. The most susceptible varieties are 104, BZ–1 and BZ–2 which may have their growing point destroyed in a severe mite attack, the plants giving the appearance of having had their apices burnt. In varieties with a tendency to branching, mite damage to the apex of the plant tends to force the development of branches (Plate IV).

There is often a period of one to two weeks of dry weather in the middle of each wet season, generally in January and June, when the crop is 6 to 8 ft. high. It was noticed at Enterprise that a mite attack generally developed at this time. If this dry period were followed by heavy rain daily for several days the attack was arrested and, if wet weather continued with heavy showers, it disappeared, not to re-appear until dry weather was again experienced just before harvest. If, on the other hand, the dry weather in the middle of the growing season was followed only by light showers, the attack developed in intensity.

Whether for fibre or seed production, jute is grown in dense stands as a broadcast crop. The spacing of the plants in the field varies from 4 to 8 in. between plants and reasonable crops will be not less than 8 ft. high at harvest; a height of 13 ft. has been obtained. The control of pests was seldom required before the crop was 3 to 4 ft. high, often not until the crop was 5 to 6 ft. high when it would be seven or

eight weeks old. The height and denseness of stand of the crop meant that effective spraying or dusting from the ground was difficult, particularly when it was borne in mind that the pests to be attacked were concentrated at the top or near the top of the plants. Moreover, insecticides had to be applied at a time when rain could be expectedly daily. The only means of access across the field without damaging the crop was along the interbed drains in the field, the length of which varied from 1,000 to 2,000 ft. The length and/or width of fields as well as wind direction ruled out the possibility of using powerful sprayers or dusters operated from dam bed roads. Any spraying or dusting machine to be used under these conditions had to be portable, light and able to be carried by one or two men walking along an interbed drain, the bottom of which was muddy. The spray or dust had to be capable of penetrating a dense stand of jute 25 ft. wide and of reaching the top of plants that might be up to 12 to 13 ft. high.

During these investigations, various types of high and low volume, hand-operated knapsack and pneumatic sprayers were tried out, together with various types of hand and machine-operated dusters, machine-operated knapsack type combination sprayers, dusters and fog dispensers, a wet and dry fog dispenser, and a tractor-mounted high/low volume sprayer for row crops and weedicide application.

Experiments in 1953-54 with the Swingfog machine proved that flea beetles and chrysomelids could be kept under control more economically by the use of toxaphene and BHC dry fogs than by sprays or dusts. When fogging, the operator walked down the interbed drain to windward of the first bed on the lee side of each field returning up the next interbed drain to windward. The thick fog produced drifted over and through the jute in a dense cloud. In certain wind conditions, the top of the jute immediately next to the drain along which the operators was travelling might not be reached by the fog. This did not matter because when the next bed to windward was fogged the fog cloud would completely envelop the jute that was missed. The fog cloud was found to drift to leeward, enveloping the jute for distances of up to 75 ft. under favourable wind conditions while, under adverse conditions, with winds of more than five miles per hour, envelopment of the crop took place for at least 40 ft. Windless conditions were unfavourable for fogging as drift was poor and the fog tended to rise vertically. The best conditions for fogging occurred when a gentle cross wind of up to about two miles per hour was blowing. There did not appear to be any deposit of the insecticide on the plant under field conditions. The fog caused the pests to fly and thus to come into contact with the fog particles. Moreover the overlap of the fog clouds in the crop while a field was systematically fogged to windward helped to kill all adult beetles in the crop. In beds 25 ft. wide any one area of jute received two or three separate clouds of fog within about 20 minutes, depending on wind conditions. The average cost of fogging per application, using Swingfog machines and excluding depreciation of the machine, was 54 cents per acre, including the cost of the insecticidal fogging-oil, labour and field transportation, with a man-hour requirement per acre of 0·30. This average cost was incurred irrespective of

whether fogging oils containing toxaphene, BHC, lindane or DDT were used. A toxaphene fogging-oil was found to be cheaper than the others and the final routine for the control of these pests comprised either two foggings with toxaphene, followed by a fogging with BHC, or one fogging with toxaphene, followed by one with BHC.

In 1954, experiments indicated that cercopids could be controlled by BHC and lindane dry fogs provided that attacks were caught early. Subsequently, the routine of toxaphene fogs followed by BHC fogs appeared to keep cercopids under control. If numerous spittle masses had developed before control measures were instituted, it might be necessary to dust the crop with a BHC dust such as 'Agrocide 3' at 12½ or 25 lb. to the acre. The Roots rotary hand duster was found to be the most efficient and dependable of this type of duster tested. Average cost of application per acre, excluding depreciation but including insecticide, was 94 cents and $1.69 at respective rates of application with a man-hour requirement per acre of 1·49 and 2·43.

As was to be expected, the control of mites on jute has proved most difficult. In the early stages of an attack the mites are to be found on the underside of curled and crinkled leaves at the tops of tall plants and are in consequence difficult to get at. Moreover, the need for control has become more urgent with the passing years because progressively greater acreages have been planted to the *capsularis* strains of the BZ varieties.

Investigations in other countries on various crops other than jute indicated that control could be obtained under greenhouse conditions by fumigation with BHC or methyl bromide. Under field conditions, limesulphur, sulphur and pyrethrum dusts gave control.

In 1954, exploratory spraying trials were carried out against mites on the variety, 104, using a parathion spray. The results were encouraging in that reasonable control was achieved on plants 5 to 6 ft. high where good coverage of the top of the plant was achieved. On taller plants where the coverage was less efficient control was indifferent. It was decided that this insecticide could not be used without serious danger to the operators, following the appearance of mild toxicity symptoms, in spite of all precautions in the field, in the operator who carried out these trials.

In 1955, trials continued, using chlordane, malathion, 'Chlorocide','P.P. Summer Ovicide' as sprays, and sulphur dust. Sulphur dust was the only insecticide to give control but difficulty was experienced in obtaining efficient coverage, using rotary dusters or machine operated knapsack dusters in a tall crop. The hygroscopic nature of the dust made it difficult to keep it in suitable condition for dusting under local conditions of high humidity. Furthermore, the pace at which the operator could walk along an often muddy interbed drain was so slow that, without complete head protection, there was serious danger to his health.

The newly-appointed agronomist in 1957 was able to devote more time to this problem and in that year tested sulphur dust together with 'Aramite', 'Akar 338,' 'Basudin' and malathion. Satisfactory control was again obtained with a sulphur dust and with 'Aramite'. Low volume air-blast spraying with a 'Motoblo' sprayer proved unsatisfactory since

the machine required considerable modification to get the spray to the top of the plants and speed of spraying did not compare favourably with pneumatic knapsack sprayers of the Cooper-Pegler 'Favori-Colibri' type fitted with extension lances. Experience indicated that the spray must be directed vertically downwards on the growing point.

In early 1958, it appeared from further tests that 'Aramite' could no longer be regarded as dependable for the control of mites. A series of exploratory trials was again laid down to observe the effect of various acaricides at varying rates of application at low, medium and high volume. The following acaricides were included: 'Sulfinette', 'Phenkapton,' 'Rogor 40', malathion, 'Aramite', 'P.P. Summer Ovicide,' 'K 101', 'Ovotran' and sulphur dust. As judged by counts of mites on samples of leaf from each treatment, none of the acaricides tested gave really satisfactory control, although the effectiveness of certain acaricides such as 'Rogor 40' was greater at high volume (100 gal. per acre) than at low volume (25 gal. per acre) while the reverse was the case with 'Aramite' plus P.P. Summer Ovicide and 'Aramite' by itself. Sulphur again gave the best control. The cost of spraying 'Aramite' with Cooper-Pegler sprayers filled by a compressor unit was $2.62 per acre, including the cost of the acaricide, and manpower required was 2·54 man-hours per acre.

The only reliable way of controlling mites on jute appeared to be by the application of sulphur in either dust or spray formulations. The application as a spray by using knapsack sprayers would, however, be impracticable, uneconomic, slow. The use of sulphur dusts dispensed by machine dusters of the 'Whirlwind' type carried on the shoulders of two men along muddy interbed drains would be practicable provided adequate protection was given to the operators. Speed in applying of control measures once an attack is noticed is essential due to the short life cycle of the mite. Consequently, the most efficient means of application of a dust or spray is by aircraft. Unfortunately, time did not permit actual tests to be carried out, but there is little doubt that high volume application of a sulphur spray containing about 5 lb. of sulphur or 60 lb. of dust per acre would achieve control.

Semi-looper caterpillars seldom became a serious pest in the field. Control was generally affected by routine fogging against flea beetles but if a build-up occurred, spraying with DDT or dusting with 'Agrocide 3' was necessary. The average costs of spraying DDT with Cooper-Pegler sprayers and the 'Motoblo' sprayer including the cost of the insecticide were, respectively, $1.80 and $2.17 per acre, man-hours per acre being 1·98 and 4·16 respectively.

Pests of Other Crops

During work on possible rotation crops, various pests were controlled.

Heavy infestations of the rice paddy-bug, a pentatomid, were controlled by fogging with toxaphene, using the same technique as already described for the control of flea beetles in jute. A BHC fogging-oil with or without pyrethrins was also effective but more expensive.

The cotton stainer complex in cotton was controlled with lindane fogs. The most useful insecticide for the control of the cotton pest complex of

stainers, pentatomids and red spider was Plant Protection Ltd.'s 3 : 5 : 40 cotton dust applied with Roots rotary dusters.

Cowpeas were attacked by chrysomelids and flea beetles and were controlled by the use of fogs as in jute.

Army-worm, *Laphygma frugiperda*, attacking maize was controlled by flooding, BHC fogs and dusting with 'Agrocide 3.' Spread from field to field was prevented with Paris green baits. No effective control of stem-borers was found.

Whenever possible, dry fogs were used for pest control both in the field and in buildings. The Swingfog proved an efficient fog producer with low maintenance and application costs per acre. Proprietary brands of ready-mixed fogging-oils were preferred to home-made formulations using diesel oil as the carrier. Fogging-oil formulations used were manufactured by the Murphy Chemical Co., the Standardised Disinfectants Co. and the Geigy Co. Ltd.

Diseases

Jute in British Guiana is fortunate in not having suffered any serious disease outbreak. Minor and isolated outbreaks of stem rots caused by *Diplodia corchori* and *Macrophomina phaseoli* have occurred. Until the spring crop of 1958, damage was negligible but, in this crop, an outbreak of these two fungi in a crop of BZ–3 resulted in a loss of plant stand of 11 per cent. and 17 per cent. respectively.

An isolated outbreak of stem-rot caused by *Diplodia corchori* was observed on the variety E.C.R.–576 in 1953 and a similar outbreak occurred in 1954. An article on jute research in 1940[9] and Mohanty[10] described damages caused by *Macrophomina phaseoli* in India and indicated methods of control. From 1954, jute seed was dusted with 'Agrosan GN' at a rate of 1 lb. per 21 lb. of seed with effective results as judged by the freedom of the jute crop from any major outbreak of stem-rot. Isolated outbreaks of stem-rot, attributed to *Diplodia corchori* appeared to be contained in trials by spraying with 'Perenox' in 1954. It never became necessary to consider field-scale spraying against stem-rots. In 1957, as a result of poor growing conditions, *Fusarium* sps. caused secondary root rots in jute 1 to 2 ft. high.

Unidentified saprophytic blue moulds attacked seed crops in the field following wet weather and reduced germination quite seriously during prolonged storage. The variety E.C.R.–576 was particularly affected, due to its prolonged seed harvest. When grown for a seed crop in the autumn, this variety cannot be harvested before January if the harvesting is to be done in one operation and the maximum yield of ripe seed obtained. With the onset of the rains in December, the ripening seed pods get wet and moulds develop on the seed. Loss of germination in storage attributed to mould attack has been known to be over 70 per cent. Damage to infected seed in storage can be reduced by floating the dry seed following threshing and discarding all seed that floats. The heavy seed that sinks is dressed with 'Agrosan GN,' following thorough drying prior to storage. By this means the seed stored has a higher initial germination capacity and loss of germination in storage is greatly reduced

compared with that occurring during storage of undressed and untreated seed. Various other non-mercurial seed dressings were tested with jute but were found to be less effective than 'Agrosan GN.'

In other crops the only disease of consequence was *Bacterium solanacearum*, causing black-arm disease in cotton. This was so severe in the second and subsequent cotton crops that the only possible varieties to plant were Sakels resistant to the disease.

Harvesting Jute

Since jute is propagated by seed, provision has to be made in any crop for the production of seed as well as fibre. With the seed rates already described and with yields averaging 400 lb. per acre for a good seed crop, one acre of seed crop should yield sufficient seed for 133 acres of a fibre crop at an average seed-rate of 3 lb. per acre.

(1) *Ribbon Production*

Bradley and Kirby [1] have described the work done at Mokwa. The harvesting and retting programme for the first jute crop to be harvested in 1952 in British Guiana was designed on the basis of the results of the Mokwa trials in 1951, suitably modified to fit the unusual field layout in British Guiana. The harvesting of a crop for ribbon can be conveniently sub-divided into five distinct phases: cutting and bundling, ribboning, drying, scutching, and baling.

(a) Cutting and Bundling

When the first harvest began in 1952, the trailed type rear-mounted tractor mower ordered had not yet arrived and male labour was employed to cut the crop with cutlasses. A strike occurred shortly afterwards. The men were replaced by women and the latter continued to cut the crop until the end of the harvest. The average cost of cutting jute by hand is not expensive, being $1.38 per acre requiring 6·23 man-hours. After cutting, the jute stems must be sorted and collected into bundles suitable for feeding to the ribboner and this operation of bundling becomes costly being $5.16 per acre and requiring 16·75 man-hours. The difficulty lies not so much in the cost of cutting and bundling but in the need for labour additional to that required for other harvesting operations at a time when labour is scarce due to the sugar-cane and rice harvests.

Towards the end of the 1952 harvest, a trailed mower of the reciprocating knife type was received and tried out, operated with a Fordson Major tractor. The mower cut the crop satisfactorily but had several drawbacks, the major ones being (a) that the operator could not give enough attention to the mower when travelling in heavy crop on cambered beds and to poor manoeuvrability on the beds. A mid-mounted, heavy-duty Ferguson mower with six-ft. knife was tried out, fitted with serrated knives (Plate V). This proved to be more easily manoeuvrable and controllable in work, and cut the crop of whatever density without difficulty. This mower was used for cutting the fibre crop until 1957 when the harvesting technique was improved further by the introduction of the Ferguson kale Cutrake (Plate VI).

A mid-mounted mower can keep three ribboners in work supplied with cut jute. When ribboning, it was found desirable that the plants should be ribonned as soon as possible after cutting, particularly if the crop were either a poor ribboner or somewhat overmature for fibre production. With beds varying in size from a half to threequarters of an acre, only about 100 to 200 ft. of bed was cut at one time in an effort to supply the ribboner with freshly-cut material. With two or three ribboners at work, one on each bed, the mower had to cross the interbed drains frequently on portable plank bridges. The technique of cutting consisted in the mower travelling down the edge of a cut bed, with the cutter bar extended over the interbed drain, cutting out a strip of jute 2 to 3 ft. wide on the adjacent bed along the edge of the drain. The next cut was made with the tractor straddling the drain, the tractor afterwards being able to operate on the bed being cut. To improve stability when straddling the drain, the off-side tractor wheels were moved outwards and flotation and steering were markedly improved by fitting large diameter front and rear tyres. The value of the large diameter front tyres were demonstrated to such effect that, within a year, the Ferguson agents had adopted them as a standard fitting for all tractors sold in the country, not only for this particular operation but for all other operations on clay soils. The large-sized rear tyres also became common on tractors operated on wet clay soils.

The cut straddling the drain required skilful driving under wet conditions. It was found subsequently that, if a tractor was driven through standing jute of any height, the damage to the crop was negligible and no difficulty was experienced in cutting the crop that had been driven over. As a result, the time-consuming cuts used to open up a bed were dispensed with. The result was that one mid-mounted mower, used as described, could keep four ribboners in work supplied with stems.

The cutting team comprised a well-trained tractor driver and either two men, or two or three women. The latter were required to move the cut stems away from the edge of the standing crop leaving a cleared space of about 18 in. to facilitate the next cut and prevent stems already cut from being cut a second time.

After cutting, the stems were sorted roughly by length into bundles of suitable size for feeding to the ribboner. The bundles were laid on either side of the bed with butts towards the centre of the bed. Women were employed on bundling, four being required to keep each ribboner in work.

A Ferguson kale Cutrake was imported in 1957. This proved to be an improvement on the mid-mounted mower after it had been modified, since it eliminated the bundlers and resulted in a reduction in the amount of labour required and a saving of $9 to $12 per day. Modifications involved raising the back and side frames, covering the floor of the Cutrake with mesh, and strengthening the pivot on which the pitman oscillates. The cutting team comprised a tractor driver and one or two labourers. The Cutrake reverses into the crop while cutting; it then moves forward and drops the load of cut stems at intervals at the side of the bed, several loads being used to make up any one pile of stems.

The stems are off loaded by the labourers. The Cutrake has simplified the cutting of the crop and one will keep three to four ribboners at work. The cost of the Cutrake is less than that of a mid-mounted heavy-duty mower. The average operating cost for harvesting jute was $3.29 per acre, man-hours required being 5·38 per acre and engine hours per acre being 3·41, excluding depreciation but including labour and fuel (Plate VII).

(b) Ribboning

Following the successful trials of an experimental reaper-ribboner at Mokwa in 1951[1], a downstriker ribboner was designed by the late Mr. J. Bradley, O.B.E., of the National Institute of Agricultural Engineering, to meet the requirements of field layout, etc., in British Guiana. The ribboner was known as the 'Elcom' after the makers and was designed to be mounted on to a Fordson Major tractor, being driven by V-belts from the power take-off shaft of the tractor. Two machines were ordered for delivery in British Guiana for use on the 1952 autumn crop. When it became clear that delivery would be delayed, the reaper-ribboner used at Mokwa in 1951 was shipped out and Mr. W. Boa of the National Institute of Agricultural Engineering came out to assist in assembling and working the machine.

The Mokwa ribboner enabled ribboning to be done in 1952. Being an experimental machine which had been much modified, it did not work particularly well but enabled the staff to gain experience of the problems involved in ribboning and in the handling of the ribbon. Modifications were required and effected during the harvest. The take-off mechanism with a flexible drive proved useless and was replaced by a manually-operated take-off bar which subsequently became a standard fitting on all ribboners. The ribbon produced contained some adhering shive but, at the time, this was not considered serious because its effect on retting had yet to be discovered. The feed rollers had to be covered with hessian to prevent slip under wet conditions. Considerable operating time was lost because of lapping of the drum and its shafts by ribbon. Labour requirements were five men and two women to operate the ribboner, and eight women to cut, sort and bundle the crop ahead of the ribboner. The capacity of the machine was 0·15 acres per hour in crop, yielding 16 tons per acre of green plant. It was concluded from these trials that jute could be ribboned as satisfactorily as *Hibiscus cannabinus* had been at Mokwa and that a simple and efficient take-off device, known as a strick bar, had been developed to enable ribbon to be collected in the form of stricks.

At the beginning of October 1952 the first Elcom ribboner was received. It was assembled and fitted to a Fordson Major tractor by Mr. W. Boa. Some crop had been retained to enable preliminary tests to be undertaken. In spite of the crop being overmature for fibre production, some valuable information was obtained on the performance of this ribboner and the modifications that were necessary (Plate VIII).

The Elcom ribboner was mounted directly on the rear end of a Fordson Major tractor, the direction of feed being at right angles to the direction

of travel of the tractor. The feed table could be folded upwards and over the feed rollers for transport purposes and consisted of a wide-moving rubber belt. In the working position the feed table extended beyond the rear wheel of the tractor for some 4 to 5 feet. The ribboner itself comprised three sets of two feed rollers which fed the stems of jute over an anvil bar, the stems being beaten downwards over the anvil by a revolving drum on the periphery of which were fixed, at intervals, a series of beater bars. The ribbon, with leaves and pieces of pith, known as shive, was discharged downwards. The ribbon was collected over a moving V-belt and discharged at the side of the ribboner.

The Elcom ribboner was found to ribbon jute satisfactorily although some shive was left adhering to the ribbon. As already mentioned, the adverse effect of this adhering shive on retting had not been determined. There was less lapping of the drum, the shafts of the drum and feed rollers than with the Mokwa machine, the output was greater and since the ribboner was mounted on a tractor, it was easier to manoeuvre than a trailed ribboner such as the Mokwa machine. The position of the feed carrier and its length permitted the ribboner to move along the edge of the bed adjacent to the bed being ribboned. The feed carrier extended across the interbed drain and this allowed the tractor with trailer, on which the stricks of green ribbon were to be loaded, to run alongside the ribboner while the latter was working.

The Elcom ribboner had to be modified by the replacement of the moving belt strick take-off mechanism with a manually operated strick bar developed earlier in the year for the Mokwa ribboner. This strick bar permitted an average output of 10 to 12 stricks per minute, each strick of green ribbon varying in weight from 3 to 6 lb. It also became clear that the beater drum should be made of a solid cylinder of steel to which the beater bars should be welded throughout their length, instead of having the spaces between the beater bars filled in with light plate spot-welded to the inside edge of the bars. The drive to the feed carrier proved unsatisfactory.

In 1953, a practicable harvesting technique was evolved in which the crop was cut by a mid-mounted Ferguson mower, bundled by a team of women working ahead of the Elcom ribboner, the bundles fed butt end first to the ribboner travelling along the adjacent bed, and the green ribbon loaded directly into a trailer which ran alongside the ribboner One tractor and three trailers were required for transporting ribbon produced by each ribboner. One ribboner was considered capable of ribboning $1\frac{1}{2}$ acres of average crop in an eight hour day. The performance of the Elcom ribboners was disappointing in that they could not clean ribbon of shive to the degree considered desirable and it was felt that it would be worthwhile testing the upstriker principle of ribboning. In an upstriker the position of the anvil bar is reversed, the top roller of the final set of feed rollers adjacent to the anvil bar becomes fixed instead of the bottom roller and the direction of travel of the beater drum is reversed. The effect of these changes is that the stems are beaten upwards instead of downwards and are scutched as they pass over the upper half of the drum before being caught on the strick bar. It was felt that

the scutching action of the drum would assist in relieving the green ribbon of some of the adhering shive which was being obtained with downstriker ribboners.

Trouble was again experienced with the drive of the feed carrier, and ways and means of improving this drive were considered. It was decided that the moving feed belt could be dispensed with and a fixed feed table used to replace it. No difficulty was experienced in feeding the ribboner from a fixed feed table, except that the feeder had to stand near to or to straddle the interbed drain.

This feeding difficulty, coupled with the tractor time wasted while a trailer was being filled alongside the ribboner, gave rise to the idea of developing a ribboner mounted on its own wheels to be fed from the rear; the ribboner in turn to be coupled to the rear of a trailer on which the ribbon is to be loaded, the whole being pulled by one tractor.

In 1954, Mr. J. S. Oliver designed and had made in Dundee an upstriker drum of 44 in. diameter with a single pair of feed rollers and an anvil bar fitted with an experimental doffing wheel instead of a strick bar. On arrival, this machine was fitted on to a locally-made two-wheeled chassis and a Petter AVI (5 b.h.p.) diesel engine was installed beneath the rollers to drive the ribboner. This was tested early in the 1954 autumn crop harvest and was referred to as the 'Hay' ribboner (Plate IX). At the same time as the Hay ribboner was being developed the old Mokwa ribboner was converted locally to an upstriker ribboner. It was also decided to convert the Elcom downstriker ribboners to trailed downstriker ribboners mounted on a two wheel chassis and driven by Petter AV2 (10 b.h.p.) diesel engines using Renolds chain drives (Plate X).

Trials undertaken during the harvest with the Hay and converted Mokwa upstriker ribboners demonstrated that the upstriker principle was superior to that of the downstriker. An improvement in the utilization of tractors and trailers, as well as a reduction in the number of labourers required, was obtained by using trailed ribboners coupled to the rear of the trailer to be loaded and both pulled by a single tractor.

The results of this work in 1954 can be summarized as follows:

(1) Confirmation was obtained that downstriker ribboners cannot produce ribbon sufficiently free of adhering shive; consequently ribbon from downstriker machines will always have to be scutched, with a resultant increase in cost of production.

(2) The Hay ribboner (upstriker with 44 in. diameter drum) produces shive-free ribbon which can be successfully collected on the strick bar provided the crop is taller than 7 ft. A doffing wheel cannot replace the strick bar.

(3) A variable-speed drive for ribboners driven by stationary engines is not necessary. A single pair of feed rollers as fitted to the Hay machine, is unsatisfactory and three pairs are necessary for efficient feeding. It is advantageous to have the bottom feed roller of the final pair (nearest the beater drum) fluted or grooved and to be able to adjust the gap between the drum and anvil while the ribboner is in operation.

(4) An upstriker ribboner with an 18 in. diameter drum (the converted Mokwa ribboner) produced ribbon free of shive except for 3 to 6 in. of pith or shive left in the butt end of the ribbon. With a drum of this diameter, plants 4 to 5 ft. in length can be ribboned successfully and caught on the strick bar.

(5) Ribbon produced by an upstriker ribboner can be satisfactorily caught on a strick bar under all conditions provided a blast of air is directed on to the forward edge of the beater drum from below.

(6) The Hay ribboner only required a 5 b.h.p. engine because of the large diameter and weight of the beater drum. Upstriker or downstriker ribboners with 18 to 28 in. diameter drums require 10 b.h.p.

(7) A beater drum diameter of 26 in. is considered more suitable than one of 18 in.

(8) The slowing-up of the feed rollers of a downstriker ribboner with a consequent increase in the number of beats per minute although producing cleaner ribbon, did not eliminate the necessity for scutching.

(9) The bundles of stems should be fed crop end first, instead of butt end first as hitherto. It was necessary to train the feeders to spread the stems of each bundle evenly over the full width of the feed table.

(10) The advantages of trailed ribboners, driven by their own engines with direct loading into a trailer to the back of which the ribboner is attached; the whole being pulled over the field by a light tractor of the Ferguson and Fordson Major type were proved. This ribboning technique saved $18.83 per acre in direct harvesting costs. The use of an upstriker ribboner effected an additional saving of $17.60 per acre, this being the estimated cost of scutching.

(11) To enable Ferguson and Fordson Major tractors to handle a harvesting unit, comprising coupled trailer and ribboner, under wet and slippery bed conditions it was found necessary to improve traction. The most efficient means found of achieving this was by fitting cage wheel extensions of the Catchpole type to the rear wheels of the tractors.

With confirmation that an upstriker ribboner was more efficient than a downstriker, and with the other data on ribboning that had been accumulated, it was possible to draw up working drawings of an upstriker ribboner based on actual results in the field. This was done by Mr. J. S. Oliver; and the engineering drawings to enable a machine to be made were by Mr. J. S. Longmuir. The Demerara Foundry Ltd., of Georgetown, British Guiana, was commissioned to make the new ribboner which was called the 'Enterprise' (Plate XI). This machine was ready for work in the 1955 autumn crop harvest. For this harvest, the Hay ribboner had been fitted with two additional pairs of feed rollers and the 44 in. drum had been replaced with one of 26 in. diameter. One Elcom ribboner was also converted to an upstriker ribboner.

As a result of field operations of the above ribboners in 1955, the following facts were established.

(1) The Enterprise ribboner was capable of ribboning one acre of average crop in an operating time of 7½ hours.

(2) Improvements were effected in the positiveness of feed and in ribboning generally of the Enterprise ribboner by replacing the smooth top roller in the final pair of feed rollers by a grooved one, thus making both rollers in the final pair grooved; by lowering the anvil bar so that the working surface of the bar was in line with the top of the roller; and by reducing the width of the bar in contact with the stems.

(3) The guard that extends from the anvil bar to the top of the drum in an upstriker ribboner was made adjustable, enabling the guard to be moved closer to or further from the drum. Flexible guards protecting the bearing and drum shaft from lapping were devised and fitted: these effectively stopped lapping of the shaft.

(4) The direction of flow and the volume of air blast from the fan were controlled by fitting an adjustable gate.

(5) A new type of hanger, considerably cheaper to fabricate for the final pair of feed rollers and anvil bar, was designed and proved successful.

(6) In spite of the above modifications, the residual 3 to 6 in. of shive that remained in the butt end of all ribbon were not removed. This was simply due to the fact that the last few inches of stem could not be held firmly enough just before and after it had passed the nip of the final pair of feed rollers. The 3 in. diameter grooved bottom roller of the final pair of feed rollers in a converted Elcom ribboner and in the Enterprise was replaced by a 4½ in. diameter grooved roller. The effect was a reduction in length of shive left in the butt ends of ribbon from 4 to 6 in. to 2 to 3 in. in both ribboners.

(7) The 26 in. diameter drum in the Hay ribboner was replaced by a 22 in. diameter drum. The effect was that shorter jute could be ribboned, provided that the final pair of feed rollers was grooved.

(8) An 18 in. diameter beater drum on the converted Elcom ribboner proved somewhat unsatisfactory and was replaced by a 22 in. drum.

(9) A new design of final feed roller groove cheaper to machine and partially self-cleaning, was tested and adopted.

(10) All ribboners were fitted with platforms for the operator of the strick bar and engines were guarded against shive and leaf debris. A hinged guard was also found necessary to cover the gap between the final and second pairs of feed rollers.

For the 1956 harvest, the Enterprise ribboner was fitted with a 5 in. diameter solid bottom final feed roller instead of one of 4½ in. diameter. The length of shive left in the butt ends of ribbon was thus reduced. The second Elcom ribboner was converted to an upstriker and fitted with a 24 in. diameter beater drum and worked satisfactorily. It was concluded at the end of harvest that the Enterprise upstriker ribboner, as modified, was an efficient jute ribboner and that no further work was

required on the development of a ribboner. Any new Enterprise ribboners would be fitted with air-cooled instead of water-cooled diesel engines.

The ribboner is manned by one feeder and an assistant feeder, a strick-bar operator who controls the rate of feed, a take-off operator who stands to the rear of the ribbon trailer and removes the strick from the bar, a woman loader on the trailer who stacks the strick of ribbon, a woman gleaner, and a tractor driver. The gleaner recovers ribbon that has fallen off the strick bar during work and has got mixed up with leaf and shive on the ground (Plate XII).

The trailer used is a normal two to three ton two-wheeled farm trailer with one hayladder fitted to the front of the trailer. A drawbar is also fitted to the trailer frame, at the rear of which the ribboner is coupled. Harvesting procedure is for the tractor with trailer and ribboner to enter a bed, crossing the field drains by means of portable bridges which were previously constructed in wood but are now made of angle iron and expanded metal, and to travel down the centre of it, stopping at intervals to ribbon the piles of jute left at the side of the bed by the cutrake. When the trailer is full, the ribboner is disconnected, the loaded trailer driven out of the field and left on the dam bed where an empty trailer is collected and taken into the field. A properly loaded trailer with the ends of the strick always laid to the centre of the railer, will carry two tons of stricks of green ribbon. One transport tractor can haul two and, if the field roads are good, three loaded trailers at one time. It is necessary to equip the strick take-off operator and the woman loader with shatterproof goggles and ear muffs to prevent damage to eyes and ears from flying shive. One transport tractor can easily take care of three ribboning teams, keeping them supplied with empty trailers and removing the loaded ones to the drying lines. Each tractor attached to a ribboner team should be fitted with a forward mounted transport box in which maintenance tools, lubricants and spares can be carried.

The average costs of ribboning and ancillary operations exclusive of depreciation and maintenance are recorded in Table XI.

TABLE XI

Operation	Total cost per acre	Man-hours per acre	Tractor hours per acre	Ribboner hours per acre
	$ c.			
Ribboning .	13 40	31·51	3·62	7·21
Gleaning .	2 52	10·80	—	—
Loading trailers in the field .	4 24	15·91	—	—
Transport to drying lines .	0 57	0·97	0·46	—

The design of an upstriker ribboner and the improvements in or relating to ribboners for jute and similar fibres which were devised in the course of the above ribboning investigations are described briefly hereunder. The working drawings of the Enterprise ribboner, incorporating all modi-

fications, have been handed over to and are available from the National Research Development Corporation of London to whom enquiries should be directed.

At the end of the Mokwa trials, it was proposed to provide a down-striker ribboner incorporating, at the front of the ribboner, a feed table defining a plane inclined upwards towards the rear of the ribboner, a plurality of pairs of feed rollers, revolvable about horizontal axes and arranged in series between the feed table and a drum revolvable about a horizontal axis and located at the rear of the ribboner. The periphery of the beater drum was to be formed with a series of equi-spaced bars and an anvil was to be disposed between the drum and the pair of feed rollers adjacent to the drum, the anvil defining with the drum a nip to which jute plants or similar fibre plants were fed, bark being stripped from the stems in the nip. This machine was unable to produce satisfactory ribbon.

An upstriker ribboner was designed in which the feed table was situated at the rear of the machine and the take-off at the front. The ribboner was mounted on a two-wheeled chassis adapted for coupling at the front to a trailer in such a way that an operator could stand on the trailer while removing ribbon from the strick bar of the ribboner. A fan was mounted under the beater drum to blow air on to the periphery of the drum and to blow the bark clear of the drum and on to the strick bar. A system of levers and shafts, screws and worm-gearing was provided to permit variation, during the operation of the ribboner, of the clearance between the drum and the anvil while maintaining the axes of the feed rollers parallel to the axis of the drum. Each roller of the final pair of feed rollers, i.e., the pair adjacent to the anvil and the beater drum, was fitted with grooves running parallel to the length of its axis. Also, the bottom roller of this pair was moveable vertically and held against the top roller by a spring. The curved shroud located above the drum could consist of sheet or perforated metal permitting the ribbon to be controlled during rotation of the drum between the shroud and the drum. One or two horizontal take-off or strick bars could be provided at the front of the ribboner being adjustable vertically and pivoted on either side of the ribboner, for partial swinging movement about the vertical axes. Finally, to prevent ribbon from wrapping itself around the beater drum shafts, the end plates of the drum were inset and a rigid dish-shaped guard, to which an annular flap of resilient material was fixed, was fitted to each end of the drum with the shaft passing through the guard. The flap masked the gap between the guard and the end of the drum thus preventing the passage of bark between the edge of the guard and the end of the drum.

With an upstriker ribboner incorporating the above features, jute plants are placed on the fixed feed table and are fed to the nip between the adjacent first pair of feed rollers. The plants are then fed through the nips of the other pairs of feed rollers to the nip between the drum and the anvil. During rotation of the drum, the bars on the drum beat the plants against the anvil, breaking the pith into short pieces and splitting the bark longitudinally. The bark is separated from the pith and the fibres in the bark remain undamaged, the length of each piece of bark or ribbon remaining unchanged. The broken pith and ribbon are carried

upwards by the drum, passing between the drum and the shroud which prevents the ribbon from falling back on to the feed rollers and at the same time scutches the ribbon. The pith and leaves fall to the ground and the ribbon is thrown clear of the drum on to the strick bar, by the speed of rotation of the drum and by the air-blast from the fan where the ribbon hangs awaiting removal by the operator.

To summarize the work on ribboning, one may say that a downstriker ribboner was found to be unsuitable for ribboning the jute varieties grown in British Guiana because the ribbon produced was not sufficiently free of adhering shive. This necessitated the testing of the upstriker principle and the subsequent design and development of an upstriker ribboner. A satisfactory harvesting technique which proved efficient on a field scale was evolved to suit the ribboner.

(c) Drying

It was thought that consideration should be given to the artificial drying of ribbon and fibre owing to the possibility of rain showers interfering with drying, particularly the drying of fibre during the wet seasons, as retting would continue throughout the year. Firms in the United Kingdom that had for many years been concerned with the manufacture of drying plant for fibres were consulted. Following detailed investigations, it was decided that the artificial drying of green ribbon was economically impossible and that the artificial drying of fibre offered no problem but that the cost per ton would be fairly high.

Meanwhile, static drying lines to enable the sun drying of green ribbon and fibre were erected. The lines were erected in blocks of 30 lines, each 300 ft. long with 3 ft. between wires, surrounded by a road on all sides. Each line was constructed with a strainer post of 8 in. minimum diameter at either end of the line, with intermediate posts of 4 in. minimum diameter at 12 ft. centres. No. 8 gauge round galvanized fencing wire was strung over the top of the posts, and was held in position by staples, the wire being 6 ft. above the ground. A hand-operated winch was fitted to one end of the wire, enabling the wire to be strained as necessary. Each block of drying lines was split up into bays by the intermediate posts running across the long axis of the drying lines. Each bay consisted of 30 wires just under 12 ft. long and stricks of green ribbon or washed fibre were loaded on to the lines from the access road on either side of the lines to a depth of 15 wires. The green ribbon was off-loaded from the trailers on to single-wheeled fibre barrows which were run under the lines in a bay on duckboards if the weather was wet. Four women were required to off-load and hang the output from one ribboner. A depth of 15 wires was considered to be the optimum depth for transport purposes without causing too much loss of time in the transport of ribbon under the lines. The heating that occurred when green ribbon remained on a trailer overnight before being unloaded had no effect either on drying the ribbon or on subsequent processing.

Green ribbon was dried satisfactorily on these lines in three days in sunny weather including the days on which the ribbon was hung on and taken down from the lines. If showers of rain had been experienced during

drying, the drying time might have had to be extended to four days. Heavy showers prolong drying time; it appears, however, that most of the rain is shed by the ribbon and little absorbed. The drying lines should be so sited that neither the long nor short axis is at right angles to the prevailing wind. The optimum layout would be the long axis of the drying lines at an angle of 30°-45° to the prevailing wind.

With a view to preventing drying stricks of ribbon and fibre running together or bunching on the lines, and, to improve drying and butting, the design of the lines was modified by fitting an 8 inches long wooden batten at right angles to the wire on the top of all posts in any one line and by running two lines spaced 4 in. apart, instead of one drying line. The strick was thrown over both lines and in this way drying was speeded up and bunching on the lines greatly reduced. Further, this method of hanging the strick greatly facilitated the butting of the stricks on the drying lines and the removal of loose shive entangled in the ribbon. This operation of butting green ribbon produced by upstriker ribboners on the drying lines eliminated shive entangled in the stricks. Provided that the work was done when the ribbon was fresh, the women could, at the same time, remove the pieces of shive remaining in the butt ends of the ribbon. If, through a labour shortage, butting had to be done when the ribbon was dry or partially dry, the butts ends could not be cleaned save at a considerable increase in cost. Butting, with its associated task of shive removal eliminated the need for scutching dry ribbon and required the addition of seven or eight women per ribboner to the drying line team of four. The amount of work involved in butting varied, being greater when overmature crop was being ribboned or when a variety was ribboning badly, due to lack of turgidity in the stems following dry weather.

As a general rule, 7,600 running feet of drying line are required to handle the daily output of each ribboner, assuming that the ribbon will be removed from the lines in three or four days. The lines can be of any convenient length with a road running parallel to the lines on either side of the block. The block of lines should not be greater than 30 lines wide, allowing the loading of up to 15 lines from either side. Average costs using the modified type of drying lines for discharging trailers alongside the drying lines and hanging ribbon on the lines are $7.05 per acre with a man-hour requirement per acre of 31·08. The cost of butting ribbon on the lines is $13.81 per acre requiring 59·05 man-hours. Both operations are done by women, the tractor driver assisting with unloading. One wheeled tractor will take care of the transportation requirements of three to four ribboners working simultaneously in the field. Three trailers should be provided for each ribboner, to take care of the transport of ribbon from the field to the drying lines and to avoid any interruption in ribboning occasioned by a shortage of empty trailers in the field.

The static drying lines described have worked satisfactorily and at no time has ribbon or fibre been spoilt by inability to dry the material on these lines. Consideration was given to the possibility of using mobile drying lines for green ribbon in the field. It was estimated that the difficulties and cost involved in setting up temporary drying lines in the field

to follow the ribboner were such when compared with static lines that experimental work was not justified.

(d) Scutching

When the importance of shive-free ribbon for retting and subsequently in the sale of fibre was realized, it became necessary to devise ways and means of scutching the ribbon to remove the shive after the discovery, in 1953, that the Elcom downstriker ribboners did not produce clean ribbon. The upstriker ribboner produced clean ribbon save for a short length of shive in the butt and crushed pith at the crop end of the ribbon, provided that the variety possessed a pith that snapped cleanly or that the crop was ribboned at optimum maturity. No difficulties arose in retting ribbon of this type. The small amount of shive was removed when the fibre was sorted and graded by cutting off the butt ends containing the shive. The crushed shive of the crop end which may be described as 'papery' shive was also removed very easily by light hackling. However, if the crop was a poor ribboner owing either to inherent poor snapping quality of the pith or to lack of turgidity in the plant, due to dry weather or to over-maturity, the ribbon produced by an upstriker—although not as dirty as that from a downstriker ribboner—would require scutching to remove adhering shive. Thus all ribbon from downstriker ribboners and certain ribbon from upstriker ribboners had to be scutched. Plants may be described as at an optimum stage of maturity for fibre production that have started to flower up to the stage when the seed capsule is less than a quarter of the normal size.

It was therefore necessary to carry out trials with a view to developing a machine that would remove adhering shive from green or dry ribbon. It was found that, if a strick of jute were held by one end and thrown over a drum revolving away from the operator, the shive adhering to and entangled in the ribbon would in a short while be thrown clear of the ribbon. The drum had to be wide enough to prevent the strick from lapping the drum but a high drum speed was not essential. Neither the 'papery' shive nor the short section of shive remaining in the butt ends of ribbon could be removed by the drum. As the 'papery' shive did not interfere with retting and could easily be hackled out of fibre during sorting, its non-removal from ribbon could be condoned. In the case of the shive in the butt end, the only solution was to cut off these butts containing shive when selecting fibre or before retting; the former choice was more acceptable.

A prototype scutcher was constructed. This consisted of two cylindrical frames made of angle iron and mounted on shafts which revolved in opposite directions from each another. The cylindrical frames were 20 ft. long, 4 ft. in diameter and the periphery of the frames was made up of angle iron on edge, mounted at equal intervals round the circumference of the frame and running parallel with the axis of the frame. The space between the angle iron bars was open. An endless conveyor belt three in. wide and studded with steel pins on which a strick of jute could be impaled, ran along the line where the two drums lay alongside each other. Suitable feed and take-off platforms were fitted. The frames or

drums revolved at about 20 rev./min. The strick of ribbon was opened out, thrown on to the feed platform and impaled on the pins of the conveyor belt about midway along the length of the strick. The conveyor belt slowly carried the strick over the revolving frames which beat or scutched both ends of the strick as it was conveyed the length of the drums, beating out adhering shive in the process.

Although the removal of entangled and adhering shive was largely satisfactory, it was found that quite a lot of ribbon, particularly short ribbon, was pulled off the pins of the conveyor and had to be collected by hand. Further, all scutched ribbon had to be butted by hand and there was no way of cleaning a section of the ribbon extending for about 6 to 12 in. on either side of the conveyor belt. The scutcher was a useful machine but was not entirely satisfactory. The building of a second prototype with a device for turning the strick and improving the conveyor's grip on the strick was being considered when a successful method of conveying a strick of fibre through the washing sluice was devised. At the same time, it was found that adhering and entangled shive including 'papery' shive and shive in the butt ends of ribbon could be easily torn out of fresh green ribbon, or dry ribbon drawn over and through widely spaced hackle pins, but that hand hackling of ribbon to clean it of shive was economically impossible, even if adequate labour had been available. A machine comb was therefore devised for cleaning enough green ribbon during harvest to enable the retting capacity of the rettery to be continuously utilized using green ribbon. After harvest, the combs would continue operating, cleaning dry ribbon in sufficient quantity to feed the rettery to capacity.

Full-scale tests of the final prototype were carried out early in 1956. It was found that the machine comb successfully cleaned both green and dry ribbon but that the throughput was better with dry ribbon because less ribbon was pulled out of the strick as it passed over and through the banks of combs. It was also found that the comb would remove adhering or entangled shive from fibre produced from ribbon that had been retted either green or dry.

The machine finally constructed used the strick moving principle invented for the washing sluice and a series of sloping frames holding hackle pins. These frames are mounted in pairs, one of each pair on either side of an endless chain conveyor. The strick of bark or fibre is held round the middle, enabling each end of the strick to fall on to and be drawn through each pair of sloping frames containing hackle pins, as the conveyor carries the strick forward along the machine. Arrangements are made for hand-feeding stricks of ribbon or fibre and for hand or machine assisted take-off of the stricks. There is also a device to facilitate the cleaning of the hackle pins. The conveyor consists of a stationary bar of hardwood secured to and along the top of a series of 'A' frames extending from the feed to delivery end of the machine. A Renolds chain carrying a series of grips at suitable intervals is arranged to pass along and move over the top of the bar; it is prevented from rising too far off the bar and so releasing the strick when under load, by a pressure plate running parallel to and over the top of the chain. The grips consist of pairs of

straight or bent pins fitted one to either side of the chain so that they lie close to each side of the bar. These pins secure and move forward any strick of ribbon or fibre laid across the bar by the feeder. The grips are attached at suitable intervals to the chain which is mounted on pulleys so arranged as to cause the chain to move along the top of the bar and engage the pins of the grips on either side of the machine. The stricks to be combed are laid across the bar at the feed end and are dragged by the chain across successive hackle frames, the grips being returned from the delivery end of the machine by the action of the pulleys. Each hackle pin frame consists of a number of hackle pins suitably mounted in a wood base with or without a reinforcing back plate of steel. Each pin frame may contain two or more sets of pins bolted to the frame. The spacing of the pins on the frames becomes closer as one moves towards the delivery end of the machine, a minimum of four pairs of hackle frames being required. To assist the removal of combed matter from the hackle pins, a frame or grid is mounted on the side of each hackle pin frame and is so arranged that an operator can tilt the grid, thus wiping the pins. When working to capacity, a machine assisted take-off or doffing device is required. This doffing wheel is fitted below the end of the delivery bar which is hollow at this point and fitted with a slot, the bar being bent downwards. The doffing wheel is fitted with a feathering pin so designed as to move in behind the strick as it moves forward and draw it off the pins of the grip as they start to move upwards away from the bar at the end of their working travel. After removing the strick from the pins of the grip, the doffing wheel causes the strick to slide forwards and downwards along the delivery bar into the take-off operator's hands. The machine requires at least 5 b.h.p.

In any mechanized jute production scheme, it would be necessary to set up one or more machine combs to remove adhering and/or entangled shive which may be obtained from part of any one harvest, even if upstriker ribboners are used. A machine comb would probably not be required if there were sufficient ribboners to ensure that all the crop was harvested at optimum maturity for fibre production. In that case, whatever shive remained in the butt and crop ends could be removed by the employment of a few extra women labourers on the drying lines to butt and clean the green ribbon. As conditions are seldom ideal, any scheme should ensure that dirty dry or green ribbon can be cleaned of shive prior to retting by the installation of a machine comb or combs.

(e) Baling Dry Ribbon and Storage

The original scheme envisaged the removal of the dry ribbon from the drying lines in the form of stricks and the production of trusses of this ribbon by a mobile trusser running alongside the lines, the trusses of dry ribbon being stored in the bonds to await retting. This sytem was used successfully for handling dry ribbon up to 1954. The trusser was that used at Mokwa[1] slightly modified to suit local conditions. The weights of trusses of dry ribbon varied round 20 lb. per truss while that for green ribbon varied around 43 lb., with an average storage space requirement for dry ribbon trusses of 450 cu. ft. to the ton.

With the installation of a Shirtcliff bale press in 1954, it was established that stricks of dry ribbon could be baled and the storage of ribbon in bales effected a great saving in storage space compared with storing it in trusses. The weight of the standard bale (48 in. × 20 in. × 26 in.) varied between 150 and 200 lb. for dry ribbon, the cleaner the ribbon the greater the weight of the bale giving a storage space requirement of 224-298 cu. ft. per ton of dry ribbon.

Since 1954, the dry ribbon has been taken off the drying lines and stricked by women, transported to the bale press, baled and the bales stacked in bonds until retting has taken place. If the dry ribbon requires machine combing, this operation may be carried out either before the ribbon is baled or immediately before retting. When compared with trussing this technique effects considerable savings in capital for buildings and recurrent expenditure. The average costs of this operation exclusive of depreciation and maintenance are shown in Table XII:

TABLE XII

Operation	Cost per acre	Man-hours per acre
	$ c.	
Taking-off and transporting dry ribbon to bale press .	4 23	15·31
Baling ribbon . . .	1 75	5·29
Transporting to and stacking bales in store . . .	0 91	2·81

The second, concluding, part of this article will be published in the next issue of Tropical Science.

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The Effect of the Placement of Ammonium Sulphate on the Yield of Rice in Northern Australia

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Summary

Investigations of the effects of placement of ammonium sulphate on the yield of lowland rice were carried out at the Kimberley Research Station in the northernmost part of Western Australia.

For both an *indica* and a *japonica* variety there was a significant increase in grain yield when ammonium sulphate was placed at three in. depth, compared with shallow or surface placement.

Deep placement resulted in an increase in both panicle weight and number. It also delayed maturity, increased plant height and, with the *indica* variety, caused an appreciable weakening of the straw.

Introduction

The response of lowland rice to the deep placement of ammonium sulphate has been reported by several workers in Japan[1], India[2], U.S.A.[3] and Brazil[4].

Since 1953 a series of experiments has been carried out at the Kimberley Research Station in the northernmost part of Western Australia (latitude 15°S.) to investigate the effect of placement of ammonium sulphate on the yield of lowland rice.

Procedures and Results

Preliminary Pot Trial

A pot trial was carried out by Lee (unpublished data) in 1953 using glazed earthenware pots each filled with three lb. air dried soil mixed with 0·25 g. superphosphate. The fertilizer treatments consisted of two rates of ammonium sulphate, 0·25 g. and 0·5 g., placed on the surface and at three in. depth, as well as a no nitrogen treatment. These treatments would be roughly equivalent to field application of two cwt./acre and four cwt./acre.

The variety used was the Burmese introduction Emata Yin, and sufficient seed was sown to permit thinning to three plants per pot. The pots were watered to saturation and maintained at this moisture level until the plants were six in. high. At this stage the pots were placed in a rice field so that their rims were at all times just submerged.

The addition of ammonium sulphate resulted in significant response of all plant characteristics listed in Table I.

TABLE I

The Effect of Deep Placement of Ammonium Sulphate in the pot trial yar. Emata Yin

Treatments	Yield of dry matter (g.)	Number of		Plant height (in.)
		Filled grains	Tillers	
Superphosphate only, on surface	2·10	5·02	3·00	12·20
Superphosphate only, 3 in. deep	2·10	4·78	3·00	12·30
Superphosphate + ammonium sulphate in an amount equivalent to field application of 2 cwt., on surface . . .	5·50	8·10	6·25	15·60
Superphosphate + ammonium sulphate equivalent to field application of 2 cwt., 3 in. deep .	7·80	9·24	9·25	18·40
Superphosphate + ammonium sulphate equivalent to field application of 4 cwt., on surface .	8·50	8·79	8·50	17·30
Superphopshate + ammonium sulphate equivalent to field application of 4 cwt., 3 in. deep .	11·70	12·48	11·25	20·80
Significant difference (P = 0·05) .	0·80	1·87	1·10	1·50

In all cases deep placement of ammonium sulphate at both rates proved superior to surface application. There was no significant difference between two cwt./acre at a depth of three in. and four cwt./acre on the surface.

Field Trials

Field trials were carried out during the 1957-58 wet season using the *indica* variety Meli No. 2, and in the 1958 dry season with the *japonica* variety Caloro. Because local experience indicated that Caloro gave a greater increase in grain yield than Meli at high levels of nitrogen fertilizer application, four cwt./acre of ammonium sulphate was used with the former variety and two cwt./acre with the latter. The same depth of placement and times of application were used in both experiments.

Except for the late application, the ammonium sulphate was placed at the depth required in the treatments by separate drilling with an ordinary seed and fertilizer drill. Immediately afterwards, in all treatments, seed, together with two cwt./acre of superphosphate, was drilled to a depth of one in. An attempt was made to ensure that the seed drill lines were as close as possible to the ammonium sulphate drill lines.

Immediately after sowing the land was irrigated and the water drained. This practice was continued at weekly intervals until the plants were

six in. high, when continuous flooding to a depth of four in. was adopted. Late application was carried out as top dressing 21 days after sowing and before flooding.

The results are shown in Table II.

TABLE II

The Effect of Deep Placement of Ammonium Sulphate in the field trials with Meli No. 2 and Caloro

Ammonium sulphate treatments	Meli No. 2 trial			Caloro trial
	Mean weight of panicles (g.)	Mean number of panicles	Yield of unhusked rice lb./acre	Yield of unhusked rice. lb./acre
3 in. deep at planting .	5·4	141	5,350	6,922
1 in. deep at planting .	3·6	132	4,457	5,440
On surface at planting .	3·7	130	4,356	5,370
On surface after 21 days .	3·8	128	4,110	4,257
Significant difference (P = 0·50) .	0·3	6	306	633

In both trials deep placement of ammonium sulphate at three in. resulted in significant yield increases, while there was no significant yield difference between treatments receiving ammonium sulphate at one in. depth and on the surface. In dry season trial with the Caloro variety late application of ammonium sulphate significantly reduced the yield, although in the wet season trial the corresponding difference with Meli No. 2 was not significant. In the latter trial, where mean panicle numbers and weights were recorded in sampling quadrats, deep placement of ammonium sulphate produced significant increases in both characters while the differences between remaining treatments were not significant.

In both experiments it has been noted that deep placement of ammonium sulphate resulted in markedly increased plant height and delayed maturity. With the *indica* variety Meli No. 2 it also led to weakening of straw and serious lodging.

DISCUSSION

The results of pot and field experiments with *indica* varieties carried out in the wet summer season as well as the results of a field experiment with a *japonica* variety in the dry winter season confirmed, under northern Australian conditions, the overseas experience that lowland rice gives considerable yield response to deep placement of ammoniacal fertilizer. In the *indica* variety, the yield increase appears to be due to increase in the weight of panicles rather than increased number of panicles.

It should be noted that in present experiments constant flooding did not take place until four weeks after application of fertilizer. Japanese workers, noted by Mitsui[1] have shown that the effectiveness of am-

monium sulphate can be influenced not only by the depth of application but also by the time of flooding. Their evidence suggests that with shallow placement of the fertilizer, delay in flooding leads to appreciable losses of nitrogen.

It should be noted also that the soils on which these experiments were conducted have pH between 7·7 and 9·4. This, according to findings of several workers [5, 6, 7], may be conducive to high nitrogen losses by volatilization when ammonium fertilizers are applied on the surface.

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A Comparison of Lindane, DDT and Malathion for the Protection of Bagged Groundnuts from Infestation by *Tribolium castaneum* (Hbst.)

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Summary

A comparison has been made of lindane, DDT and malathion water-dispersible powders for effectiveness in protecting clean, bagged groundnuts from infestation by *Tribolium castaneum* (Hbst.) during a storage period of six months.

Miniature jute sacks filled with groundnuts were sprayed externally with the insecticides. Single treatments, applied at the beginning of the storage period, were compared with repeated monthly applications. Conditions of cross-infestation were simulated by adding beetles at fortnightly intervals.

The rate of development of infestations was assessed by monthly sampling and final infestations were measured by sieving all the groundnuts.

All treatments gave some control of infestation, the repeated monthly applications being more effective than single applications. The most effective treatments were the monthly doses of malathion at 40 and 80 mg. per sq. ft.

Introduction

The Rust-red flour beetle, *Tribolium castaneum* (Hbst.), is a major pest of decorticated groundnuts in West Africa.[1] It has been shown[1, 2, 3] that heavy infestations of *T. castaneum* cause powdering of the kernels and, besides reducing the quantity of oil, increase its free fatty acid content. Howe *et al.*[4] recorded weight losses of 8½ lb. per 189 lb. sack of decorticated nuts where heavy infestations developed during storage. Furthermore, Cotterell[5] found that infested groundnuts caused trouble in transit, and during storage at the ports, by infesting other export crops such as cocoa and palm kernels.

Howe *et al.*[4] showed that, in northern Nigeria, although effective control was achieved by fumigating stacks of bagged groundnuts *in situ*, reinfestation by *T. castaneum* occurred very quickly. BHC, applied as a dispersible powder to the outside of the stacks showed promise for protection against reinfestation. Subsequently, Duerden *et al.*[6] concluded that, under these conditions, lindane remained effective for only about four

days. Using impregnated jute sacks, Pingale and Majumder[7] showed that DDT and lindane gave relatively poor, long-term protection against *T. castaneum* when compared with aldrin and dieldrin. Malathion has been shown to be effective against *T. castaneum* in field trials[8] and in laboratory tests[9].

An urgent requirement of the industry, therefore, is a contact insecticide which is effective against the beetle after application to the outside of the sacks containing decorticated groundnuts. To be economically acceptable, such an insecticide must remain effective for several weeks after application and, since it is to be used near foodstuff, must be of low mammalian toxicity. With these points in mind, some laboratory trials have been carried out comparing lindane, DDT and malathion dispersible powders for effectiveness in protecting bagged groundnuts from infestation by *T. castaneum*.

Method

Miniature jute 'B' twill sacks, measuring 12 in. × 18 in., were each filled with about 1$\frac{3}{4}$ lb. of sieved, fumigated groundnuts and stitched as in normal practice. Half of the sacks were fitted with 9 in. slide fasteners down the centre of one side so that, during the experiment, samples of the nuts could be removed with minimum disturbance to the insecticidal treatment.

The entire outer surface of the filled sacks was sprayed with dispersible powders of lindane, DDT and malathion, both as single treatments and at monthly intervals during storage, at rates calculated to give the following actual deposits:

Lindane .	40 and 80 mg. per sq. ft.
DDT . .	100 and 200 mg. per sq. ft.
Malathion .	40 and 80 mg. per sq. ft.

Four replicates were made for each treatment and eight untreated sacks were used as controls.

Sacks were stored individually on hardboard surfaces, and, in order to confine the beetles, each sack was isolated by a narrow, sticky band. Conditions of cross-infestation were simulated as far as possible by tipping within the sticky band, at fortnightly intervals, 75 *T. castaneum* adults, three to five weeks old. The number able to infest the sacks was a little lower than 75 since some insects wandered into the sticky band and were removed. Before re-infesting the sacks each fortnight, all dead insects were removed from the hardboard, sticky band and from the outside of the sack.

In order to assess the rate of build-up of infestations, samples of about four oz. of nuts were removed from the sacks and examined eight, twelve, sixteen and twenty weeks after the original treatment. Each sample was a composite of seven small samples drawn from similar positions in each bag. After six months all experimental nuts were sieved and the numbers of live and dead insects recorded.

Temperature throughout the experiment was not closely controlled but ranged mainly between 70°F. and 80°F.

Results and Observations

No treatment had any apparent repellent effect, beetles crawling freely over all treated surfaces.

Counts of knocked down and of dead beetles, made 24 hours after the insects had been added, indicated that, when freshly applied, lindane was rather more rapid in action than either DDT or malathion. This is illustrated in Table I, which is based on the counts of knocked down and of dead insects found outside the sacks three days after the first treatment and one day after insects had been added. Since this was the first treatment, counts could be made on both the single-treatment sacks and those which were later to receive repeated doses: each percentage relates, therefore, to a total of about 450 insects. Counts were concerned only with insects which were affected before they could penetrate the sacking: the table demonstrates, therefore, relative rates of action and not relative toxicities.

Table I

Rates of action, against *T. castaneum*, of three-day-old deposits of insecticide on sacking

Treatment	Deposit mg. per sq. ft.	Per cent. knocked down or dead after 24 hours
Lindane .	40	23·3
	80	37·4
DDT . .	100	8·2
	200	19·1
Malathion .	40	17·6
	80	28·7

Comparison of counts of insects from the samples and from the full-scale sieving showed that the sampling gave only a general indication of the degree of infestation present. This was probably because the insects were very unevenly distributed within the bags of nuts and tended to concentrate in the centre of the underside. However, the counts of insects in the samples, Table II, show that:

1. All treatments gave some protection against infestation.
2. With the probable exception of 80 mg. per sq. ft. malathion, no treatment remained fully effective for eight weeks.
3. Both the weight of deposit and the frequency of application of malathion appear to be very important. At 40 mg. per sq. ft. the effective life appears to be between four and eight weeks, since a single dose gave control for less than eight weeks whereas repeated monthly doses virtually prevented infestation. On the other hand, a single dose applied at 80 mg. per sq. ft. appeared to be effective for at least eight weeks.
4. Similarly, lindane at 80 mg. per sq. ft. appears to have an effective life of between four and eight weeks.

TABLE II

Infestation by *T. castaneum* of groundnuts in sacks treated with insecticide: rates of development of infestation as indicated by samples

Treatment	Rate of application mg. per sq. ft.	Single dose								Monthly dose							
		8 weeks		12 weeks		16 weeks		20 weeks		8 weeks		12 weeks		16 weeks		20 weeks	
		mean no. insects per sample	per cent. alive	mean no. insects per sample	per cent. alive	mean no. insects per sample	per cent. alive	mean no. insects per sample	per cent. alive	mean no. insects per sample	per cent. alive	mean no. insects per sample	per cent. alive	mean no. insects per sample	per cent. alive	mean no. insects per sample	per cent. alive
Lindane	40	6·0	75·0	15·5	77·4	12·5	84·0	29·0	79·3	2·0	100·0	4·0	62·5	4·0	50·0	8·5	41·2
	80	1·5	66·7	4·5	100·0	9·0	61·1	12·5	92·0	0·0	0·0	1·0	0·0	0·5	0·0	3·5	28·6
DDT	100	3·0	100·0	18·5	89·2	29·5	78·0	60·0	83·3	2·0	100·0	3·0	66·7	4·5	66·7	5·5	54·5
	200	3·0	83·3	7·0	64·3	10·0	60·0	20·0	55·0	4·5	88·9	7·5	46·7	6·5	30·8	6·5	23·1
Malathion	40	9·5	89·5	8·5	88·2	19·5	64·1	42·0	60·7	0·5	0·0	2·5	20·0	3·0	33·3	6·0	8·3
	80	1·0	0·0	2·5	60·0	4·0	37·5	6·6	38·5	0·5	0·0	0·0	0·0	2·0	0·0	2·0	0·0
Control	—	7·75	100·0	69·0	96·7	170·25	96·8	200·5	96·5	—	—	—	—	—	—	—	—

Final sievings showed that no treatment had achieved absolute control since all sacks contained some insects. In some sacks relatively few live insects were found although it was apparent that breeding had occurred, for the number of dead insects at all stages of development was greatly in excess of the number used to infest the sacks. To demonstrate the extent to which breeding had taken place, the total number of insects (alive and dead) recovered from the sieved groundnuts and from the sack and the surface of the board enclosed by the sticky band, was divided by the number of beetles added (approx. 2,600 per treatment) and expressed in Table III as the 'factor of increase of infestation'.

A comparison is also made of the number of living insects of all stages in the treated and untreated sacks. This is expressed in Table III as 'overall control' and is the percentage reduction of infestation in relation to the infestation of the control sacks (approx. 8,000 per sack).

Counts confirmed that all treatments gave some control of infestation and showed that no single treatment gave adequate protection for the entire six months period.

The most effective treatments were the monthly doses of malathion at 40 and 80 mg. per sq. ft.; there were very few live insects at the end of the experimental period and only a little breeding had taken place.

Lindane at 80 mg. per sq. ft. monthly and DDT at 200 mg. per sq. ft. monthly also gave good control but the DDT treatment had allowed a serious degree of breeding to take place, as indicated by the 'factor of increase of infestation'.

TABLE III

Infestation by *T. castaneum* of groundnuts in sacks treated with insecticide: increase of infestation and overall control after six months' storage

Treatment	Rates of application mg. per sq. ft.	Single dose		Monthly dose	
		Factor of increase of infestation	Overall control per cent.	Factor of increase of infestation	Overall control per cent.
Lindane .	40	4·4	73·98	3·8	95·77
	80	2·9	85·53	1·7	98·30
DDT . .	100	6·3	72·01	3·6	95·89
	200	6·1	89·12	2·7	98·94
Malathion .	40	6·0	77·09	1·6	99·95
	80	3·8	95·26	1·2	99·98
Controls .	—	13·1	—	—	—

DISCUSSION

It seems likely from the results of this experiment that insecticide applied externally to bagged commodities can give a high level of protection against cross-infestation by *T. castaneum*. Clearly, in practice, bags would not be sprayed all over, nor would treatment be as thorough as that given

under laboratory conditions. Bearing in mind, however, that a single treatment of malathion at 80 mg. per sq. ft. protected bagged nuts for eight weeks, good practical protection should be achieved if each layer of bags is sprayed as a stack is built and the outside of the completed stack is sprayed at monthly intervals.

Of the insecticides used, malathion showed the most promise. Because DDT has a higher mammalian toxicity than malathion, and lindane has already been used against *T. castaneum* with only limited success in the tropics[6, 8] further trials will, at present, be limited to malathion. In these trials it is proposed to relate results obtained with sacklets and with full-sized sacks because it seems likely that the kill of breeding insects, associated with some treatments and referred to earlier, was increased by the use of very small sacks which required the insects to remain at all times within a few inches of the treated surface. Further information on the effects of rates of dosage and frequency of treatment will also be obtained.

Acknowledgement

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The Effect of Insect Infestation on the Quality of Decorticated Groundnuts with Special Reference to Storage at High and Low Humidities

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Introduction

The results of a preliminary investigation to study the effect of insect infestation on the harvested groundnut *Arachis hypogaea* L. have been published[1], [2]. It was shown that there is a general increase in the acid value of the oil extracted from the kernels and dust, and a decrease in the protein content of the kernels; these results can be correlated with the degree of insect infestation. Further experimental work has now been carried out on Nigerian decorticated groundnuts to study in more detail the effect on their quality of insect infestation and storage at high and low humidities.

The investigation was divided into two parts, Part I dealing with the effect of insect attack on the kernels, and Part II with the effect of relative humidity on kernels previously damaged by insects.

Method

In Part I of the experiment the kernels were subjected to high and low infestations of *Tribolium castaneum* (Hbst.) (larvae and adults), *Caryedon gonagra* (F.) (larvae) and *Trogoderma granarium* Everts (larvae) for three months at 30°C. and 70 per cent. relative humidity. At the end of the period each sample was well mixed and then divided into three batches using a Boerner sample divider. At the same time the insects and dust were removed from the kernels of one batch by sieving and careful separation. The moisture and oil contents, the acid value of the extracted oil, and the protein content of the de-oiled meal were then determined on the one batch.

In Part II of the experiment, the other two batches were stored for three months as kernels, and dust separated by sieving only, one at a high humidity (75 per cent. relative humidity) and one at a low humidity (48 per cent. relative humidity). At the end of this time the samples were analysed as in Part I.

Part I

Decorticated groundnuts of Nigerian origin were hand-sorted and allowed to equilibrate with 70 per cent. relative humidity and at 30°C. for an initial period of four weeks before the cultures were infested. These conditions were maintained throughout Part I of the experiment, and details of the cultures are given in Table I.

The cultures of *Tribolium castaneum* adults were sieved every week to remove larvae and pupae; the adults were counted and the numbers maintained at the original level. The dust obtained by sieving contained only very small larvae. Thus, before returning the dust to the culture, it was exposed for a few minutes to chloroform vapours to kill these stages. Investigation had shown that chloroform did not affect lipolysis in ground kernels.

The cultures of *T. castaneum* larvae were set up and after two to three weeks were sieved every two days. The pupae and adults were removed and counted, and all larvae were returned to the kernels to complete their development. Thus, approximately one generation of adults was allowed to develop on the kernels.

Since the adults of *Caryedon gonagra* do not feed, groundnuts were infested by allowing females not more than eight days old (at the peak of their egg laying period) to lay eggs on the kernels over a certain period of time. The eggs are sticky and adhere to the kernels and, as soon as the larvae hatch, they burrow into the kernel where they feed and grow. In completing development a hole about one-quarter the size of the kernel is excavated. It is very unusual for a larva to leave the kernel into which it has bored on emergence from the egg until it has finished feeding and completed its development; a habit which is quite different from that of the other two species used in these experiments. Six weeks after the first eggs had been laid the second generation of adults began to emerge and were removed daily.

The adults of *Trogoderma granarium* also do not feed. The groundnuts were therefore infested with young larvae (first and second instar) which continued to develop without pupating for 10 weeks at 30°C. Since there were no pupae present, the temperature was raised to 35°C. which had the desired effect of initiating pupation. At the latter temperature the relative humidity control was not adequate, and the result was a reduction of the moisture content of the kernels. The adults and pupae were removed from the cultures at three to four day intervals until there were no larvae visible external to the kernels.

Samples of uninfested kernels used as controls were placed on trays to a depth of two in. and covered with muslin and kept under the same conditions of temperature and humidity as the infested kernels.

At the completion of Part I of the experiment the kernels in each culture were sieved (10 mesh per one in. wire gauze) and brushed to remove all loose insects, frass and skins. The kernels and dust were then weighed, and the number of insects per unit weight of kernel in each culture was calculated as an assessment of the infestation (Table II).

The kernels from all replicates (usually six) of each group of cultures (Table I) were mixed and divided into three lots by means of a Boerner sample divider.

The dust and skins from each batch were mixed by stirring and divided into three equal parts by weight. Each part was placed in a glass tube and kept with the equivalent kernels.

One of the three batches of kernels had the dust separated from it by opening each kernel and carefully removing all exuviae and frass.

The moisture and oil contents of the kernels were then determined and also the acid values of the extracted oils and the extractable protein contents of the de-oiled meals. The moisture contents were determined by heating the kernels for three hours at 130 $\pm$ 3°C. and the oil contents by extracting 15 g. of the kernels with light petroleum, b.p. 40-60°C. for eleven hours. At intervals, the extraction was discontinued and the sample crushed and ground until finally all the material passed a 16-mesh sieve. The acid values of the extracted oils were determined by Method 1 in British Standard 684 : 1950, p. 31, while the following method was used for the determination of the extractable protein contents of the de-oiled meals. This method is given in full, as details concerning it have not previously been published.

2 g. of the well-mixed de-oiled meal were weighed into a tared 50 ml. centrifuge tube and exactly 40 ml. of 0·1 per cent. sodium hydroxide added. The meal and the liquid were well mixed and allowed to stand for 10 minutes. The tube and its contents were then shaken intermittently by hand over a period of 30 minutes and finally centrifuged for 10 minutes. The supernatant liquid, together with a small amount of floating material, was then carefully poured off through a tared crucible, having a 1 × 1 sintered glass disc. The filtrate was collected in a flat-bottomed tube contained in a Buchner flask. The residual meal was shaken with 25 ml. of the 0·1 per cent. sodium hydroxide solution and centrifuged for 10 minutes. The supernatant liquid was again poured off through the crucible, but this time the filtrate was discarded. This operation was repeated once more. The meal was then similarly washed with two portions of 25 ml. of ethyl alcohol. The meal remaining in the centrifuge tube and on the filter was then dried to constant weight at 100°C. The initial filtrate was treated as follows:

(a) 5 ml. was pipetted into a 100 ml. Kjeldahl flask for determination of nitrogen;

(b) three drops of mixed indicator (methyl red and methylene blue) were added to the remainder as described on p. 389 of Vol. 1 of "Hydrogen Ions," by H. T. S. Britton (3rd Edition, Chapman and Hall, Ltd., London, 1942), and sulphur dioxide was passed in a slow steady stream to precipitate the protein. The end point was taken when the indicator assumed a very light violet colour. This mixture was then centrifuged for 10 minutes and 5 ml. of the clear supernatant liquid pipetted into another Kjeldahl flask for determination of nitrogen.

The digestion was carried out using 5 ml. of concentrated sulphuric acid, 1 g. potassium bisulphate, and 5 drops of a 1 per cent. solution of

copper selenate. After it had become clear green in colour the mixture was heated for a further 30 minutes. The nitrogen was determined by absorbing the ammonia in decinormal sulphuric acid and titrating the excess acid with decinormal sodium hydroxide solution (methyl red indicator).

If T1 was the titration figure for the 5 ml. of de-proteinated solution, T2 the titration figure for 5 ml. of the initial alkaline extract, F the factor for the decinormal sodium hydroxide, and 5·8 the conversion factor of N to groundnut protein then:

$$\text{Extractable protein} = \frac{(T1-T2) \times 8 \times 5{\cdot}8 \times F \times 0{\cdot}0014}{2} \times 100 = P$$

$$\text{Extractable protein on moisture-free basis, per cent.} = \frac{P \times 100}{100 - L} = P_{MF}$$ (L = loss on drying at 100°C.)

$$\text{The residual meal, per cent.} = \frac{\text{Total weight of residual meal} \times 100}{2} = M$$

$$\text{The residual meal on moisture-free basis, per cent.} = \frac{M \times 100}{100 - L} = M_{MF}$$

Summarizing results

Extractable protein	=	P_{MF}
Residual meal	=	M_{MF}
Water solubles (by difference)	=	S
		100

The moisture content of the de-oiled meal was determined by drying to constant weight at 100 ± 0·5°C.

The moisture and oil contents of the dust were determined and also the acid values of the extracted oils. The moisture contents were determined by drying to constant weight at 100 ± 0·5°C. and the oil contents were determined by extracting for eleven hours with light petroleum b.p. 40-60°C. The acid values of the oils were determined as above. The results of these analyses are given in Table II.

Part II

At the termination of Part I of the experiment, the remaining two batches of kernels were kept for a further period of three months at 30°C. and constant relative humidity. One batch was stored at 48 per cent. relative humidity and the other at 75 per cent.

The relative humidities were maintained in two metal cabinets by saturated solutions of sodium chloride to give a relative humidity of 75 per cent. and lithium chloride to give a relative humidity of 48 per cent. An internal circulation of air was maintained by a fan in each cabinet which drew air across the surface of the salt solution on the lowest shelf and blew it out along the top shelf. The kernels were placed two to three in. deep in crystallizing dishes with a diameter of 125 mm. and were covered with muslin.

Until the end of the storage period, it was undesirable to break open these kernels to remove any insects that might be inside, and it was decided to ensure that the kernels were uninfested by fumigating them. Since fumigation might cause an undesirable change in the chemical composition of the kernels, it was eventually decided to subject the cultures to carbon dioxide for about a week. An exposure period to carbon dioxide of one week was apparently too short because a few *T. castaneum* survived. In view of this, the cultures were periodically sieved to reduce to a minimum the damage caused by the small numbers of insects present. This sieving helped to reduce the small amount of mould contamination which occurs at 75 per cent. relative humidity.

Control kernels which had been stored at 75 per cent. relative humidity during the first part of the experiment were placed in batches at the low and high humidities respectively to correspond with the insect damaged cultures. Finally all the samples were analysed and the results are given in Table II.

An experiment with half nuts was set up by carefully dividing whole kernels, uninfested by insects, into two parts by separating the cotyledons and leaving the embryo attached to one of them. Three samples of these half nuts were stored for three months at 30°C. and 70 per cent. relative humidity when one sample was analysed. The remaining two samples were stored at 30°C. and 75 per cent. and 48 per cent. relative humidity respectively, and after three months were analysed, and the results given in Table V. Control experiments using whole uninfested kernels were run at the same time.

Although all loose insects were removed from the cultures by sieving at the beginning of this part of the experiment, a certain number, plus skins and frass, still remained at the end of the experiment, within and between the cotyledons of the infested kernels. At the same time as each kernel was opened and adulterants removed, a record was kept of the number of infested and uninfested kernels in each replicate. They were then weighed and the average loss in weight per kernel was calculated (Table II).

Discussion

The quantity of dust produced in the most highly infested cultures of *T. castaneum* (393-395 adults per 100 g. kernels) is high (4·1 per cent. by weight) in comparison with that which has been sieved from sacks of groundnuts (Table III). As can be seen, the amount of dust produced by comparable infestations under field storage and laboratory experimental conditions is similar although it is impossible to estimate accurately the quantity produced under field conditions. As Howe[3] indicated, the figure obtained is minimal as some dust is lost by filtration through the sacking, especially during handling, and only a percentage of all the dust present is removed from the interstices of the infested kernels by sieving. Moreover, uptake of moisture, especially by the more hygroscopic dust, during storage in areas of high relative humidity, will minimize direct loss in weight. It has been calculated from data made available by A. A.

Green, following his experimental work on groundnut infestation in the Gambia 1954-55, that the average infestation of seven 170 lb. sacks of decorticated Gambian groundnuts was 62 adults and larvae per 100 g. of kernels, of which 65·8 per cent. were *Tribolium* spp., 31·8 per cent. *Oryzaephilus mercator* and 2·4 per cent. *Cryptolestes ferrugineus*. These sacks of kernels were stored for 16 weeks when 2·0 per cent. dust was produced (Table III).

As can be seen from Table II, there is no loss in the oil and protein contents of the infested dust-free groundnuts under the conditions of insect infestation and storage employed in the investigation.

Insect infestation has a marked effect on the quality of the oil, for the acid value of the oil increases with the degree of infestation (Table II). However, the humidity at which the groundnuts are stored does not appear to have affected the acid value of the oil, except in two cases: (a) *C. gonagra* at the level of infestation 288 insects/100 g. kernels gave acid values of 3·9 and 6·8 mg. KOH/g. oil at 48 per cent. and 75 per cent. relative humidity respectively; (b) *T. granarium* at the level of infestation of 146 insects/100 g. kernels gave acid values of 4·8 and 7·0 at the low and high humidity respectively (see Table II).

A comparison of Tables II and IV shows that the dust contains much less oil than the groundnuts themselves, that is the dust contains from 2·0 to 30 per cent. of oil compared with an average of 51 per cent. for groundnuts free from dust. The acid value of the oil extracted from the dust is also very much higher, that is from 30 to 150 mg. KOH/g. oil compared with less than 10 mg. KOH/g. oil for oil extracted from the groundnuts.

However, an apparent anomaly is that the acid values of the oils extracted from dust stored at 48 per cent. and 70 per cent. relative humidity are of the same order of magnitude, but the acid value of the oil extracted from dust stored at 75 per cent. relative humidity is much lower.

The results of the direct loss in weight of kernels due to insect infestation (Table II) are variable, and not comparable with the quantities of dust produced. For instance, the quantity of dust produced by *T. castaneum* larvae (infestation 33 larvae/100 kernels) is only 0·1 per cent., whereas the loss in weight calculated on these kernels is 10·0 per cent.

The number of kernels that have been infested by comparable infestations of the different species of insects varies with the differences in the feeding behaviour of the insects. It can be seen (Table II) that the higher infestations of *T. castaneum* larvae (230 larvae/100 g. kernels) have attacked about 10·0 per cent. more kernels than the medium infestations (129 larvae/100 g. kernels). Similar results have been obtained for *T. granarium* larvae, but the number of kernels infested by *C. gonagra* larvae does not compare with the degree of infestation. The results indicate that the *T. castaneum* and *T. granarium* larvae wander from kernel to kernel in the course of their development, and that *C. gonagra* larvae do not wander, a fact confirmed by observations on their behaviour.

The quality of the groundnuts is not affected to any appreciable extent by storing in the form of half-nuts (Table V) at 30°C. either at 48 per

cent. relative humidity or at 75 per cent. relative humidity. The oil content of the groundnuts is not altered, nor is the protein content of the de-oiled meal, whilst the acid value of the oil is almost the same as that of the corresponding control samples.

Conclusions

Caryedon gonagra, *Tribolium castaneum* and *Trogoderma granarium* cause considerable loss in weight and deterioration in the quality of the oil of groundnuts when stored at the optimum conditions for the development of these species, i.e., 30°C. and 70 per cent. relative humidity.

The free fatty acid content of kernels previously infested by these insects is not affected by storing at a higher relative humidity of 75 per cent. provided mould does not develop, or at a lower humidity of 48 per cent. which, in any event, does not affect the rate of development of the insects. Therefore, from a practical point of view, the quality of West African groundnuts cannot be improved by storing at low relative humidities.

References

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(2) *Pest Infestation Research* (Department of Scientific and Industrial Research), 1954, 46.

(3) Howe, R. W., 'Entomological problems of food storage in Northern Nigeria'. *Bull. ent. Res.*, 1952, **43**, 111-144.

TABLE I

Details of cultures maintained at 30°C. and 70 per cent. relative humidity during Part I of the Experiment

Culture	Replicates in lb. glass jars	Original infestation insects/kernels	Final infestation adults/100 g. kernels*	Duration of experiment (weeks)
Tribolium castaneum Adults		Adults		
0-7 days (no larvae)	24 × 1	25/50 g.	46	12
	24 × 1	25/50 g.	46	12
	24 × 1	200/50 g.	395	12
	24 × 1	200/50 g.	393	12
Tribolium castaneum		2nd instar		
Larvae (no adults)	6 × 2	50/100 g.	33	11
	6 × 2	200/100 g.	129	12
	6 × 2	400/100 g.	230	12
Caryedon gonagra		Eggs		
Larvae	6 × 2	10♀ 50♂ (2 days)	151	12 to 13
	6 × 2	10♀ 50♂ (7 days)	288	12 to 13
Trogoderma granarium		1st instar		
Larvae	6 × 2	100	146	22
	6 × 2	200	253	22

* The figures given here have all been calculated to relate to 100 g. of kernels for purposes of comparison

Table II

Results of the Examination of Insect Infested Groundnuts

Infestation of sample	Oil content (moisture-free basis), per cent.		Acid value of the extracted oil, mg. KOH/g. oil		Extractable protein content of de-oiled meal (moisture-free basis), per cent.		Loss in weight of infested kernels, per cent.	Dust, per cent.	Infested kernels, per cent.
Tribolium castaneum									
Part I—Initial damage									
70 per cent. relative humidity, 30°C.									
*(6·3 per cent. moisture content)	Infested	Control	Infested	Control	Infested	Control	—	—	—
12 weeks duration									
larvae 33/100 g. kernels . .	51·4	51·6	2·5	2·1	40·0	42·0	—	0·1	—
„ 129/100 g. kernels . .	52·2	52·5	3·9	2·2	40·3	39·6	—	0·7	—
„ 230/100 g. kernels . .	52·2	52·5	5·3	2·2	40·7	39·6	—	1·8	—
adults 46/100 g. kernels . .	50·9	52·6	4·1	2·1	34·1	39·1	—	0·9	—
„ 46/100 g. kernels . .	51·5	52·3	4·6	2·2	37·6	41·6	—	1·1	—
„ 395/100 g. kernels . .	52·0	52·6	9·2	2·1	37·3	39·1	—	4·1	—
„ 393/100 g. kernels . .	52·2	52·3	9·4	2·2	39·7	41·6	—	4·1	—
Part II									
48 per cent. relative humidity, 30°C.									
*(4·8 per cent. moisture content)									
12 weeks duration									
larvae 33/100 g. kernels . .	52·3	53·4	2·8	2·4	37·7	39·4	10·0	—	24·5
„ 129/100 g. kernels . .	52·3	51·1	3·9	2·1	39·4	38·4	15·5	—	42·9
„ 230/100 g. kernels . .	53·3	51·1	6·3	2·1	40·0	38·4	14·1	—	56·6
adults 46/100 g. kernels . .	52·0	51·3	3·3	2·1	36·8	37·1	20·4	—	37·0
„ 46/100 g. kernels . .	52·6	52·0	4·1	2·0	40·2	38·9	13·4	—	43·7
„ 395/100 g. kernels . .	52·7	51·3	9·5	2·1	39·4	37·1	17·4	—	83·3
„ 393/100 g. kernels . .	52·0	52·0	8·8	2·0	39·9	38·9	15·1	—	78·1

* Determined by heating the ground kernels for four hours at 113·5°C.

TABLE II—*continued*

RESULTS OF THE EXAMINATION OF INSECT INFESTED GROUNDNUTS

Infestation of sample	Oil content (moisture-free basis), per cent.		Acid value of the extracted oil, mg. KOH/g. oil		Extractable protein content of de-oiled meal (moisture-free basis), per cent.		Loss in weight of infested kernels, per cent.	Dust, per cent.	Infested kernels, per cent.
Tribolium castaneum									
Part II—continued									
75 per cent. relative humidity, 30°C.									
*(7·3 per cent. moisture content)									
12 weeks duration									
larvae 33/100 g. kernels . .	51·6	51·8	2·8	2·0	39·9	34·3	14·5	—	20·6
„ 129/100 g. kernels . .	51·4	50·8	3·3	2·2	39·8	39·4	10·5	—	44·3
„ 230/100 g. kernels . .	52·2	50·8	6·4	2·2	41·5	39·4	10·3	—	54·0
adults 46/100 g. kernels . .	52·0	51·9	4·6	1·9	38·0	36·2	14·3	—	46·2
„ 46/100 g. kernels . .	52·0	51·9	4·3	2·3	40·2	37·3	14·0	—	39·8
„ 395/100 g. kernels . .	51·7	51·9	9·1	1·9	37·2	36·2	22·6	—	88·5
„ 393/100 g. kernels . .	51·4	51·9	9·6	2·3	38·2	37·3	18·9	—	83·6
Caryedon gonagra									
Part I—Initial damage									
70 per cent. relative humidity, 30°C.									
*(6·3 per cent. moisture content)									
12-13 weeks duration									
larvae 151/100 g. kernels . .	52·6	52·5	3·5	2·2	39·0	39·6	—	3·8	—
„ 288/100 g. kernels . .	52·7	52·5	3·5	2·2	37·0	39·6	—	8·9	—
Part II									
48 per cent. relative humidity, 30°C.									
*(4·8 per cent. moisture content)									
12 weeks duration									
larvae 151/100 g. kernels . .	52·2	51·1	3·5	2·1	40·8	38·4	17·5	—	40·6
„ 288/100 g. kernels . .	53·6	51·1	3·9	2·1	37·6	38·4	18·7	—	21·6

* Determined by heating the ground kernels for four hours at 113·5°C.

TABLE II—*continued*

RESULTS OF THE EXAMINATION OF INSECT INFESTED GROUNDNUTS

Infestation of sample	Oil content (moisture-free basis), per cent.		Acid value of the extracted oil, mg. KOH/g. oil		Extractable protein content of de-oiled meal (moisture-free basis), per cent.		Loss in weight of infested kernels, per cent.	Dust, per cent.	Infested kernels, per cent.
Caryedon gonagra									
Part II—continued									
75 per cent. relative humidity, 30°C.									
*(7·3 per cent. moisture content)									
12 weeks duration									
larvae 151/100 g. kernels . .	51·2	50·8	3·5	2·2	38·9	39·4	23·1	—	39·7
„ 288/100 g. kernels . .	51·8	50·8	6·8	2·2	37·4	39·4	21·7	—	28·6
Trogoderma granarium									
Part I—Initial damage									
70 per cent. relative humidity, 30°C.									
*(6·3 per cent. moisture content)	Infested	Control	Infested	Control	Infested	Control	—	—	—
22 weeks duration									
larvae 146/100 g. kernels . .	51·5	51·4	5·1	2·5	38·8	40·7	—	0·6	—
„ 253/100 g. kernels . .	51·5	51·4	8·9	2·5	34·2	40·7	—	1·2	—
Part II									
48 per cent. relative humidity, 30°C.									
*(4·8 per cent. moisture content)									
12 weeks duration									
larvae 146/100 g. kernels . .	53·3	52·4	4·8	2·1	36·1	36·7	17·2	—	25·8
„ 253/100 g. kernels . .	52·2	52·4	10·9	2·1	38·9	36·7	12·9	—	37·9
75 per cent. relative humidity, 30°C.									
*(7·3 per cent. moisture content)									
12 weeks duration									
larvae 146/100 g. kernels . .	54·1	52·0	7·0	1·9	38·1	39·7	15·6	—	25·3
„ 253/100 g. kernels . .	54·2	52·0	11·3	1·9	38·3	39·7	18·8	—	38·8

* Determined by heating the ground kernels for four hours at 113·5°C.

TABLE III

COMPARISONS OF INFESTATIONS AND DUST PRODUCED IN 200 LB. SACKS OF DECORTICATED GROUNDNUTS IN THE GAMBIA, NIGERIA AND IN A LABORATORY EXPERIMENT

	Insects, per 100 g. kernels	Dust, per cent.	Storage, weeks
Gambia (Green, 1954-55)	62	2·0	16
Nigeria (Hall, 1953)	—	0·3 to 1·6	26
Nigeria Hall, 1953)	—	1·0 to 2·0	72
Nigeria (Howe, 1952)	—	1·2 to 5·3	39 to 52
Present experiment	46	0·9	12

TABLE IV

RESULTS OF EXAMINATION OF SAMPLES OF DUST FROM INFESTED GROUNDNUTS

Sample of dust sieved from cultures of:	Relative humidity at which dust was stored for 3 months, per cent.	Moisture content, per cent.	Oil content (moisture-free basis), per cent.	Acid value of extracted oil, mg. KOH/g. oil
Caryedon gonagra	75·0	17·1	1·6	32·2
,, ,,	70·0	7·8	32·0	68·1
,, ,,	48·0	5·9	32·0	77·0
Tribolium castaneum	75·0	11·4	2·6	95·1
,, ,,	70·0	12·0	17·3	151·0
,, ,,	48·0	7·9	15·5	146·8
Trogoderma granarium	70·0	12·7	17·0	145·9
,, ,,	75·0	Insufficient dust available for determination		
,, ,,	48·0			

TABLE V

RESULTS OF EXAMINATION OF UNINFESTED HALF NUTS STORED AT 30°C. FOR 3 MONTHS AT HIGH AND LOW HUMIDITIES

Relative Humidity	Description of Sample	Moisture Content, per cent.	Oil Content (moisture-free basis), per cent.	Acid Values of Extracted Oil, mg. KOH/g. oil	Extractable Protein Content of De-oiled Meal (moisture-free basis), per cent.
Low 48 per cent.	Uninfested half nuts Control	5·4	52·7	2·5	39·2
	Uninfested whole kernels	4·6	51·1	2·1	38·4
High 75 per cent.	Uninfested half nuts Control	7·9	53·2	2·9	40·8
	Uninfested whole kernels	7·8	50·2	2·2	39·4

Notes

The United Kingdom Market for Canned Pineapple.—Canned pineapple is one of the most popular of the canned fruits marketed in the United Kingdom and, in recent years, approximately one quarter of the total imports of canned fruit have consisted of pineapple, consumption of this pack being only exceeded in most years by peaches.

Before the war, about 90 per cent. of the United Kingdom imports of canned pineapple, which amounted to some 943,000 cwt. in 1938, were provided by Malaya. The bulk of the remaining 10 per cent. was supplied by the United States and consisted of choice grade Hawaiian pineapple, although small quantities were obtained from Australia, Formosa and the Union of South Africa.

In the years immediately after the war, imports were very much reduced, largely owing to the almost complete destruction of the Malayan canned pineapple industry, and in the years up to 1949 shipments from all sources were less then 60,000 cwt. per annum. With the gradual recovery of the Malayan industry, the considerable expansion of production in Australia and the Union of South Africa, and the development of the Kenya canned pineapple industry, total imports into the United Kingdom increased steadily from 118,000 cwt. in 1950, to 947,000 cwt. in 1954. Since 1954, imports have continued to rise, and in 1958 reached the record level of 1,412,000 cwt.

Although shipments of canned pineapple to the United Kingdom from the Federation of Malaya and Singapore have increased steadily during the five year period 1954 to 1958 and reached 627,000 cwt. in 1958, Malayan canned pineapple has not regained its pre-war dominance of the British market. Greatly increased supplies have been obtained from the Union of South Africa and shipments from that country amounted to 529,000 cwt. in 1958. In the years 1954, 1955, and 1956, Australia also sent large quantities to this market. However, owing to crop failures in 1957 and 1958, Australian exports of canned pineapple in these two years were at a very much reduced level, and in 1958, only amounted to 81,000 cwt., compared with 311,000 cwt. in 1955. In addition, imports of canned pineapple from Kenya have increased considerably from some 25,000 cwt. in 1954 to over 90,000 cwt. in 1956. Since then they have fallen to 77,000 cwt. in 1957 and 79,000 cwt. in 1958. Supplies have also been obtained from Formosa and, since 1955, China has provided moderate quantities of canned pineapple for the British market. Until 1957, imports from the United States and Hawaii were negligible. However, since then, small quantities have been imported under licence and in 1958, these amounted to rather less than 18,000 cwt. Further details of United Kingdom imports of canned pineapple are given in the table attached to this note.

The greatly increased quantities of canned pineapple which have become available in the United Kingdom during the past five years have caused very unsettled market conditions, particularly in view of the very heavy imports of other canned fruits. It may be considered that, from time to time during the past three years, supplies of canned pineapple on this market have been in excess of requirements. In 1958, in particular, the market was over-supplied and stocks were only cleared when importers and distributors sold cheaply. In the opinion of certain members of the trade the level at which the supply and demand for the fruit was equated was below the original cost. The decline in the price paid for canned pineapple on this market is shown by the fact that, in 1956, the average value of imports was about £7 19*s.* per cwt., but in 1957 it had fallen to £6 6*s.* per cwt. and in 1958 was only £5 15*s.* per cwt. Exporters in Malaya, Australia and the Union of South Africa have all attempted to try and stabilize the market by fixing, at the beginning of each season, minimum export prices for canned pineapple sold to the United Kingdom. However, such schemes have not been able to halt the downward trend in values, since many exporters have been forced to offer considerable discounts for purchases of large quantities, in order to move supplies.

In the first six months of 1959, imports of canned pineapple were 687,000 cwt. compared with 708,000 cwt. during the same period of 1958. However, it is interesting to note that, from January to June of 1959, Australia provided some 29 per cent. of the total United Kingdom imports of canned pineapple, compared with only 2 per cent. for the same period in 1958, while the Union of South Africa provided 21 per cent. compared with 39 per cent. for January to June 1958 and the Federation of Malaya and Singapore 41 per cent. compared with 49 per cent. The fact that Australian exporters, faced with the disposal of a greatly increased pack this year compared with 1957 and 1958, have managed to regain a considerable portion of this market, at the expense of other exporters, is due mainly to the following important factors. For years now the major part of Australian exports of canned pineapple to the United Kingdom has consisted of choice grade fruit marketed under the Golden Circle brand label and in many parts of the country this label is well-known with an established reputation for good quality fruit. During this year Golden Circle has not only been heavily advertised in the press and on television but, in addition, Australian exporters have given promotional allowances and display material, which have enabled multiple stores, in particular, to sell at very cheap prices, whilst bringing Golden Circle pineapple much into the public eye. In consequence, considerable stocks of Golden Circle pineapple have been sold, especially in southern England; in the Midlands and parts of the industrial north, there is a traditional demand for Malayan canned pineapple, particularly the 16 oz. flat can of cubes and up to now all other brands of pineapple have found it difficult to break into this market.

So far, competition from Hawaiian pineapple on the United Kingdom market has been negligible. Imports made early in 1958 were still available in retail shops at the beginning of 1959, a fact which many buyers consider indicates that any pre-war prestige enjoyed by Hawaiian pineapple on this market has now been completely forgotten. According to the trade, the British public wants cheap canned pineapple, and housewives are not prepared to pay high prices for Hawaiian fruit, even when it is packed under the well-known labels of Libby and Del Monte.

To summarize the current United Kingdom market position for canned pineapple, production in countries such as Kenya, which have not previously supplied the British market, together with the considerable expansion of the South African and Australian canned pineapple industries and the recovery of the Malayan industry, has caused the market to become over-supplied. This, combined with the difficulty of selling brands of canned pineapple not well-known in this country, has undoubtedly depressed the market and caused prices to fall. In fact, some members of the trade consider that most producers will now have to investigate fully the economics of production in relation to their costs and the returns from the present market. Competition is likely to become increasingly fierce and the recent marketing methods adopted for the Australian pack indicate that the emphasis in the future will be more and more on brand advertising. The United Kingdom market for all varieties of canned fruit is very highly competitive at present with different fruits from many countries freely available to British buyers and, in view of this situation, the following advice has been offered to exporters by one of the directors of a leading firm of multiple grocers. Only good quality fruit should be exported and the packs should be consistent and reliable. The labels of the packs should have a shelf or gondola appeal, i.e., the labels should be well designed in a modern non-fancy style, with clear typography (with the ever-growing number of self-service stores, this is of increasing importance). If possible, the fruit should be packed under an easily identified brand name which should be printed prominently on the labels, and supplies must be continual throughout the season.

*United Kingdom: Imports of Canned and Bottled Pineapple**
Quantities in hundredweights

From:	1954	1955	1956	1957	1958	1959†
Australia	277,154	311,239	246,600	74,646	81,296	200,353
Kenya	24,719	68,963	90,362	77,529	79,091	31,034
Federation of Malaya	71,358	67,756	71,686	64,527	120,386	80,740
Singapore	269,169	392,343	395,018	495,515	507,100	204,666
Union of South Africa	255,511	211,870	265,251	339,456	528,814	147,256
Other Commonwealth countries	14,553	7,685	14,342	13,643	5,340	5,260
China	—	11,129	11,131	8,440	25,486	2,970
Formosa	33,897	149,534	137,693	52,436	44,915	10,496
Hawaii	(a)	(a)	(a)	(a)	12,869	2,502
United States	(a)	(a)	(a)	(a)	4,701	1,969
Other foreign countries	548	2,439	481	1,445	1,726	247
Total	946,909	1,222,958	1,232,564	1,127,637	1,411,724	687,493
Value	*£8,135,381*	*£8,615,142*	*£8,749,040*	*£7,117,824*	*£8,149,947*	(b)

* Source: *Annual Statement of The Trade of the United Kingdom*, 1957, **2**; and *Fruit Intelligence*, 1959, **8**, No. 9, 30; 1959, **9**, No. 3, 29.
† January to June.
(a) Not available; imports, if any, included with 'other foreign countries'.
(b) Not available.

Book Reviews

NUTRITION OF THE LEGUMES. Proceedings of the University of Nottingham Fifth Easter School in Agricultural Science 1958. Edited by Professor E. G. Hallsworth. x + 359 pp., 8½ × 5½. (London: Butterworths Scientific Publications, 1958.) Price 55*s*.

The Leguminosae is one of the largest families of flowering plants, second only to the Compositae among dicotyledons. The importance of legumes in an economic agricultural system has been appreciated for many years, but the scientific basis for their use was laid down less than 100 years ago by Bousingault in his pioneer researches during the 1870's. The almost unique ability of plants of the Leguminosae to fix atmospheric nitrogen and thus be largely independent of the nitrogen present in the soil, has been of enormous value, not only in the temperate agricultural regions of the world but also in the tropics.

The aim of the group of investigators which met at the Fifth Easter School in Nottingham, was to see whether the nutrition of the legumes differed in any way from that of plants of other families. The 24 papers presented and recorded in this volume have been placed in five categories. Part I, The Plant Component; Part II, The Rhizobial Component; Part III, The Symbiotic System; Part IV, Biochemical Aspects, and Part V, Field Aspects. Most of the papers are highly specialized and some are of a controversial nature.

One such paper is that devoted to 'Nitrogen Fixation by Non-legumes' by Dr. Bond of the University of Glasgow. It must come as a surprise to many to learn that certain non-legumes possess nodule bearing bacterial colonies capable of nitrogen fixation. The total number of species involved is about 190 and all are trees or shrubs. Although this particular paper would seem to be irrelevant to discussions on the legumes, no doubt much useful information is applicable to the problem as a whole.

Two papers of interest to tropical agriculturists are 'Lime in Relation to the Nodulation of Tropical Legumes', by Dr. D. O. Norris and 'Some Factors Affecting Nodulation in the Tropics', by G. B. Masefield. Both authors stress the dearth of published information on tropical legumes as compared to the wealth of literature available on legumes in temperate agriculture. Emphasis is given to the mistake of applying *in toto* principles laid down for legumes in temperate regions to the tropics. This is well illustrated by the author in his reference to a piece of experimental work carried out on legumes in the tropics, where the wrong assumptions were drawn due to a deep-rooted belief in previous work carried out in a temperate climate.

In addition to the 24 papers, an account is given of eight demonstrations which were given at the School.

The subject is one which must interest all those engaged in the agricultural sciences and it is hoped that further meetings of this school will devote time to the discussion of the nutrition of various other important families of plants employed in agriculture. Each paper ends with references to work cited, and also brief accounts of the discussions which followed the reading of the papers. The volume also contains a list of members who attended the School. The volume is well indexed containing both a plant index and a general index.

P.C.C.

THE WEALTH OF INDIA. INDUSTRIAL PRODUCTS. Part IV. F-H. (with index). Chief Editor, B. N. Sastri. xvi + 304 pp., 11 × 9 (New Delhi: The Director General, Council of Scientific and Industrial Research, 1957.)

This volume, comprising articles commencing with the letters, F., G. and H., follows, in the main, the pattern of the earlier parts of the series*. An attempt

Colon. Pl. Anim. Prod. 1950, *I*, Nos. 1 & 4, 78, 326 ;
Colon. Pl. Anim. Prod. 1952-3, *III*, No. 3, 262 ; and *Trop. Sci. I*, No. 3, 220.

has been made to trace the development of the industries dealt with and to describe their present position; the principal raw materials and their sources and availability are indicated, and statistical data are presented.

Fish Oils

The article on fish oils gives a balanced description of the importance of these oils, and of the main varieties which are of interest in India. Information is also provided about the fatty acid composition of liver oils obtained from sharks caught in Indian waters, and of the vitamin A content of liver oils of the Elasmobranchs. Apparently, shark liver oil products are manufactured in India and statistics concerning the growth of their production in the Madras and Bombay States are provided.

Flour Milling

A detailed account of the methods used in India for the milling of wheat is given, and the types of flour produced, described. Most wheat flour is produced in small stone mills (Chakkis) which generally yield a whole meal flour (Atta), but some refined flour (Maida), is also produced in modern roller mills.

A short section describing the factors which determine the baking quality of a wheat flour is included, and statistics of the production of roller milled wheat flour in India, the imports and exports of wheat flour into and from India, and the value of imports of flour mill machinery into India are given.

Glandular Products

There is a longish entry on glandular products. The first part of this gives a brief review of the principal endocrine and other glands and their active principles. Within its compass, the account is reasonable as regards established knowledge, but is weak on more recent developments and references thereto. For example, the section on the steroids of the adrenal cortex says little or nothing about current production of these substances from diosgenin and hecogenin (the latest reference being dated 1952), while 'delta steroids' of the prednisolone type are not mentioned; in the case of insulin, the elucidation of its structure is noted but without reference to Sanger's papers, and glucagon ought perhaps also to have received brief notice as another pancreatic secretion that complicates the action of insulin. The second part of the entry is concerned with the Indian glandular products industry, and includes in tabular form a certain amount of statistical information about imports of such products, average weight of certain glands, and numbers of animals slaughtered.

Glycerine

The article on glycerine deals not only with its manufacture from fat by saponification and hydrolysis, but also with the so-called synthetic glycerine. A large proportion of the total production of glycerine in the United States is now manufactured from propylene, a by-product of the petroleum refining industry, and glycerine can also be manufactured by the fermentation of carbohydrates. In India, the main source of glycerine is from spent soap lye, and its production there has increased considerably during the period 1948 to 1956. Imports of, glycerine into India amounted to several thousand hundredweight annually up to the year 1945, but they had almost vanished by 1947. Since then the imports have been usually less than 10 cwt. per annum.

Gur

The article gives a comprehensive survey of the gur industry in India. Cane gur and its manufacture are described in some detail and reference is made to the different kinds of equipment used in the various states. The storage, composition and uses of cane gur are also discussed. Other types of cane gur such as cream jaggery, neutral gur, molassine gur, Chaku-Minjha gur, Andarki gur and Shakkar are mentioned.

Approximately 60 per cent. of the cane sugar crop is utilized for the production of gur in India and, although reliable statistics on the actual production of gur are not available, estimates based on the cane crop used for this purpose indicate a net production of around 2·5 million tons per annum.

Apart from cane gur, palm gurs produced from the sap of palmyra (*Borassus flabellifer*), date palm (*Phoenix sylvestris*), coconut palm (*Cocos nucifera*), and the sago palm (*Caryota urens*), are also described and details concerning their manufacture and composition are given. In general, the article is well illustrated and contains some interesting statistics concerning the production of gur in the individual states.

Hides and Skins

The livestock population of India is the highest in the world and it is, therefore, appropriate that the subject of Indian hides and skins has been dealt with at some length. The reader is first given a detailed account of the structure and properties of skin, particularly in relation to leather manufacture, and of the chemical composition of its constituents. Particulars of the grain characteristics and leather making properties of different types of material are supplied and an account of the damage caused by infection and disease together with current methods of prevention and control is also included.

There follows a critical résumé of the Indian industry as a whole and information concerning flaying and curing, as practised in the various states, is accompanied by an appraisal of the resultant losses to the industry caused by serious defects in processing. A useful account is given of the collection, marketing and distribution of hides and skins and the quality of pelts in relation to grading practices is also discussed. A short account of the storage and uses of Indian hides and skins in leather manufacture is provided.

The article concludes with a review of production and trade statistics and much useful information is summarized in tabular form. In general, the monograph should be of value to those desirous of information relating to Indian hides and skins; it is well illustrated and furnished with adequate references to the literature

R.D.C., A.J.F., L.H.G.-B., and W.D.R.

PERFUMES, COSMETICS AND SOAPS, WITH SPECIAL REFERENCE TO SYNTHETICS. By William A. Poucher, F.P.S., F.R.P.S. Volume I. Being Dictionary of Raw Materials together with an Account of the Nomenclature of Synthetics. Sixth Edition. 1959, xvi + 463 pp., $8\frac{1}{2} \times 5\frac{1}{2}$. (London: Chapman and Hall, Ltd.). Price 75*s*.

Poucher's three-volume work, *Perfumes, Cosmetics and Soaps*, is too well known, particularly in the industries which it is intended to serve, to need any further introduction here. The present volume is stated to be a revision of the fifth edition, published in 1942. In the intervening period of eighteen years, the range of raw materials used in perfumes and toilet preparations has not increased to any great extent and the book contains no more than seven or eight new entries.

The notes on lavender oil, irone and one or two materials of less importance have been brought up-to-date, but others appear to have been overlooked. One would like to have seen, for example, mention of Formosa as an important source of citronella oil; of Guatemala as a source of both citronella oil and lemongrass oil; and of the fact that Mexico is now by far the largest producer of lime oil. The method of van Dijck and Ruys for the preparation of terpeneless oils is still referred to as in process of 'being patented'; in fact, the method has been patented for a number of years and oils prepared by this method are now available commercially. No mention is made of 'lignin' vanillin, which is now being used to an increasing extent at the expense of vanillin made from eugenol.

The book contains a number of errors, mostly of spelling, which have persisted from previous editions, and it is disconcerting to read, on p. 26, that 'Mr. A. C. Stirling is to-day acknowledged as one of the leading authorities' on ambergris, when, in fact, Mr. Stirling died in 1942; it is to be regretted that the opportunity was not taken to revise the text more thoroughly. There is no doubt, however,

that the book will continue to be regarded as a useful work of reference by all concerned with the manufacture of perfumes and toilet preparations.

E.B.

EFFICIENT USE OF FERTILIZERS (Revised and enlarged Edition), F.A.O. Agricultural Studies No. 43, edited by Vladimir Ignatieff and Harold J. Page. xxi + 355 pp.; 9 × 6 (Rome: Food and Agricultural Organization of the United Nations, 1959). Price 22*s.* 6*d.* or $4.50.

In these days when rapidly-increasing populations in many parts of the world threaten to make the Malthusian fear a reality, any publication which offers authoritative guidance on increasing the fertility of the land for food production deserves to be read by all concerned in solving this most urgent and vital problem.

The *Efficient Use of Fertilizers*, originally published in 1949, but now extensively revised and enlarged, has been specially written for the agricultural planner, for all who, as advisers and teachers working with farmers and their organization, are concerned with enlarging understanding of fertilizers and manures. The farmer himself, and the agricultural student, will also find the book a mine of useful information.

Ninety-six soil and crop specialists working in 34 countries have pooled their knowledge and experience for this volume. The result is a monograph of very wide scope which nevertheless, takes care to give enough detailed and specific information to enable the reader to adapt these principles to his local conditions. Up-to-date information is given on plant nutrients, on the physical and economic factors affecting application of fertilizers and on modern concepts of the most effective use of fertilizers in crop production and the maintenance and improvement of soil fertility.

The relationship of fertilizers to crop rotation, erosion control, irrigation, drainage, liming and other practices are fully and clearly described.

One chapter is devoted to a discussion of 31 major world crops, their physical soil requirements, their nutrient demands and their general fertilizer needs.

Another chapter deals in detail with the farm economics of using fertilizers.

If full use is made of present scientific knowledge and technology for crop production, great progress can be made in building happier and healthier lives for millions of under-privileged people whose plight may constitute the greatest threat to more harmonious international relations. This monograph, written in concise and simple language, with numerous illustrations and beautifully printed and produced, makes a significant contribution to these aims.

M.K.

RECEIVED FOR NOTICE

ADVANCES IN COFFEE PRODUCTION TECHNOLOGY. Edited by B. Sachs and P. G. Silvain, 96 pp., 9 × 12. (New York: The Spice Mill Publishing Co. Inc., 1959.) Price $3.00.

This publication is a world-wide summary of coffee research. It outlines existing knowledge and shows the direction of efforts to extend that knowledge. Leading coffee scientists co-operated in preparing the material which deals with such subjects as: recent advances in knowledge of coffee trees; the supply of better planting material; mineral nutrition; the mechanization of cultural operations; biological control of insect pests; and factors affecting the inherent quality of green coffee.

AGRICULTURAL INSECTS OF EAST AFRICA. By R. H. Le Pelley, x + 307 pp., 9 × 6. (Kenya: East Africa High Commission, Nairobi, 1959.) Price £2 2*s.*

This publication, compiled by a former Senior Entomologist, Agricultural Department, Kenya, comprises a list of East African plant-feeding insects and mites, with their host plants, their parasites and predators, giving distribution by territories and references to the literature, together with lists of stored products, insects and introduced insects, mainly covering the period 1908 to 1956.

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Compiled by Miss V. Clarke

Comprising the more important reports, articles, etc., contained in publications received in the Library for the three months, June to September 1959.

*The publications issued by the Governments of the Colonies and Protectorates can be obtained from or through the Crown Agents for Overseas Governments and Administrations, 4 Millbank, Westminster, S.W.*1. *Applications for Dominion, Northern and Southern Rhodesian Government publications may be made to the Offices of the High Commissioners or Agents-General in London.*

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